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OHIO RIVER BASIN COMPREHENSIVE SURVEY. VOLUME V. APPENDIX D. WA--ETC(U)
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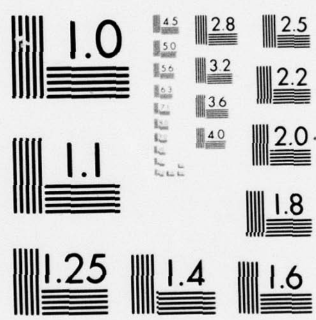
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VOLUME V

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NW

OHIO RIVER BASIN

COMPREHENSIVE SURVEY

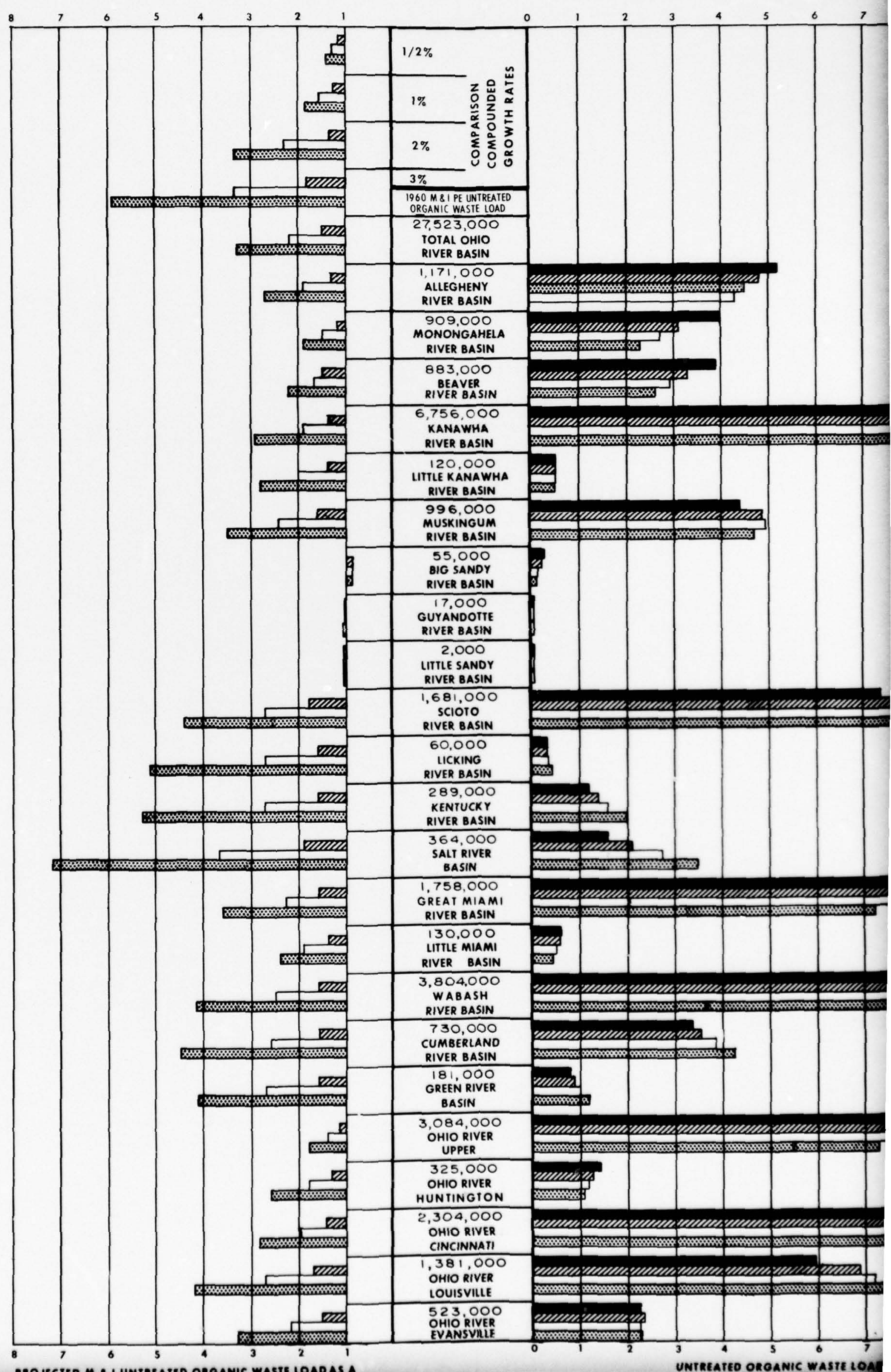
Appendix D

Prepared by
U.S. Department of the Interior
Federal Water Pollution Control Administration
Ohio River Basin Project
in cooperation with U.S. Departments of
Agriculture; Army; Commerce;
Federal Power Commission; Health, Education and Welfare
and participating states.

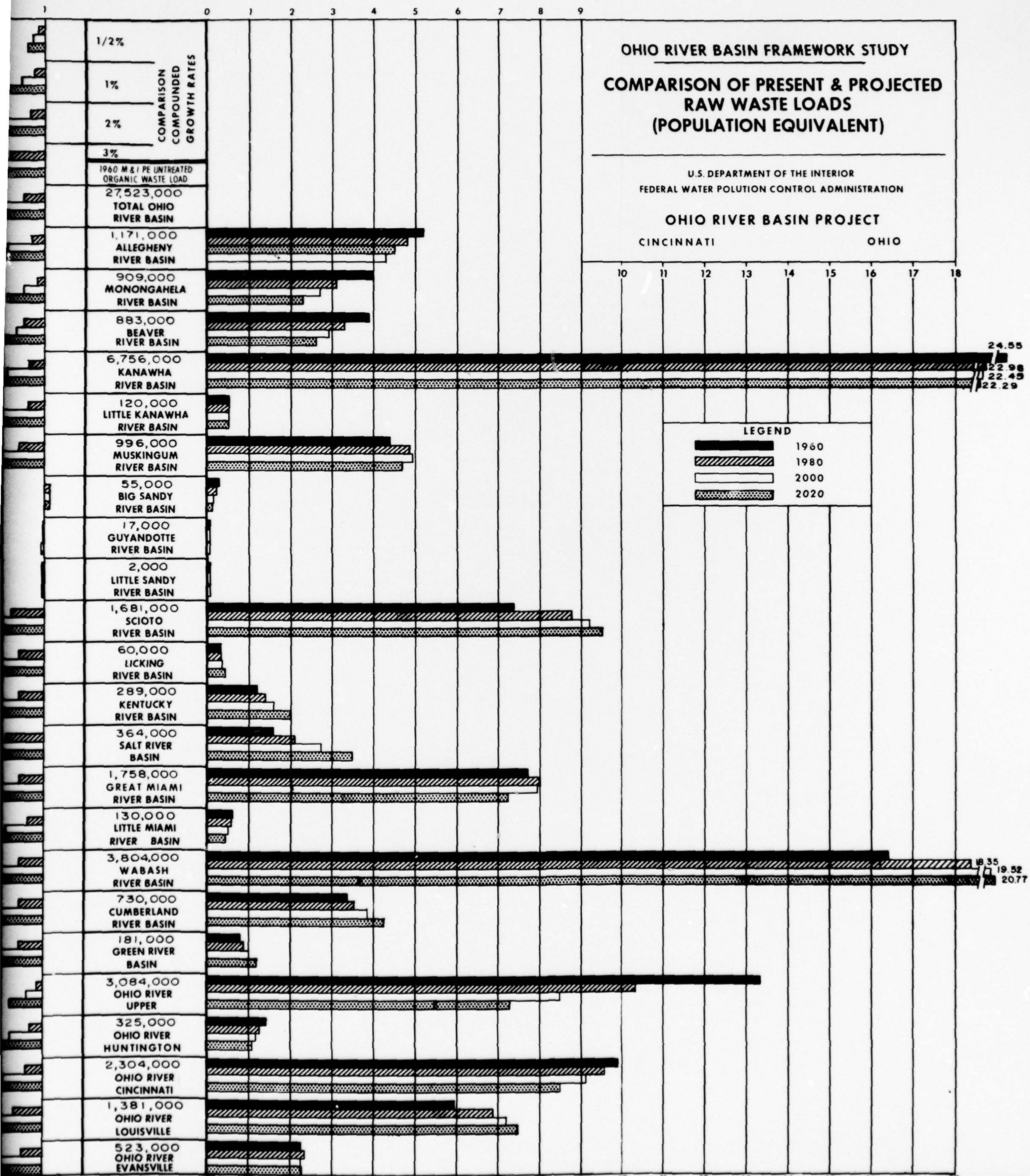
WATER SUPPLY AND WATER POLLUTION CONTROL

U.S. ARMY ENGINEER DIVISION, OHIO RIVER-CINCINNATI, OHIO

[redacted]



1/2%
1%
2%
3%
COMPARISON COMPOUNDED GROWTH RATES
1960 M & I PE UNTREATED ORGANIC WASTE LOAD
27,523,000 TOTAL OHIO RIVER BASIN
1,171,000 ALLEGHENY RIVER BASIN
909,000 MONONGAHELA RIVER BASIN
883,000 BEAVER RIVER BASIN
6,756,000 KANAWHA RIVER BASIN
120,000 LITTLE KANAWHA RIVER BASIN
996,000 MUSKINGUM RIVER BASIN
55,000 BIG SANDY RIVER BASIN
17,000 GUYANDOTTE RIVER BASIN
2,000 LITTLE SANDY RIVER BASIN
1,681,000 SCIOTO RIVER BASIN
60,000 LICKING RIVER BASIN
289,000 KENTUCKY RIVER BASIN
364,000 SALT RIVER BASIN
1,758,000 GREAT MIAMI RIVER BASIN
130,000 LITTLE MIAMI RIVER BASIN
3,804,000 WABASH RIVER BASIN
730,000 CUMBERLAND RIVER BASIN
181,000 GREEN RIVER BASIN
3,084,000 OHIO RIVER UPPER
325,000 OHIO RIVER HUNTINGTON
2,304,000 OHIO RIVER CINCINNATI
1,381,000 OHIO RIVER LOUISVILLE
523,000 OHIO RIVER EVANSVILLE
8 7 6 5 4 3 2 1
0 1 2 3 4 5 6 7
PROJECTED M & I UNTREATED ORGANIC WASTE LOADAS A



UNTREATED ORGANIC WASTE LOADS POPULATION EQUIVALENTS
PERCENT OF BASIN TOTAL

FIGURE 7

OHIO RIVER BASIN COMPREHENSIVE SURVEY

ERRATA SHEET

VOLUME V, APPENDIX D - WATER SUPPLY AND WATER POLLUTION CONTROL

Remove old pages and insert new pages as indicated below.

Page 52
Page 5-21
Page 5-43a, Table 12a
Page 5-43c, Table 12a
Page 5-44a, Table 13a
Page 5-44c, Table 13a
Page 68, Figure 7

from steel plants, toxic metal wastes, phenols and other taste and odor producing substances from coke and chemical plants, brines, sulphates, color producing substances, and silt from coal washing operations.

Phenolic compounds, while of minor importance from the biochemical oxygen demand standpoint, give rise to offensive tastes and odors in public water supplies. Their removal within the water treatment plant is difficult and costly.

The raw municipal and industrial waste loads generated in the Ohio River Basin approximate 28 million in population equivalents, of which about 63 percent is presently removed by waste treatment before entering the stream. The basins generating the largest quantities of waste in relation to the total basin are the Kanawha, Wabash, Upper Main Stem Ohio, Ohio River Main Stem-Cincinnati, Great Miami and Scioto Rivers in order of magnitude. These six basin areas account for 70 percent of the total organic load generated in the basin. Figure 7 compares the present raw waste loads generated in each tributary basin compared to the total Ohio River Basin.

Projected Municipal and Industrial Wastes

Figure 7 illustrates how each tributary basin raw waste loads are projected to increase in relation to the total Ohio River Basin. Absolute projected increases over the present base are shown on the left on the figure for the time periods 1980, 2000, and 2020 and are compared to different growth rates for the same time periods at the top of the page.

The Kanawha and the Wabash River Basins have the largest and the second largest amount, respectively, of the organic waste load generated of the basin tributaries. The Kanawha and Putnam Counties, in the lower Kanawha River Basin, account for 94 percent of the organic waste load generated in the Kanawha River Basin. The metropolitan Indianapolis area accounts for about one-third of the domestic and commercial and almost one-half of the industrial organic load generated of the entire Wabash Basin. The upper main stem area has the Pittsburgh complex as the major contributor of wastes, the Kanawha River has the Charleston complex, the Great Miami River has the Hamilton, Dayton, Middletown area and the Scioto has Columbus. All of these areas are metropolitan areas which contribute the major portion of the municipal and industrial wastes of the individual basins.

VI WATER QUALITY CONTROL

Kanawha River Basin

Present and Projected Waste Loads

Present raw waste loads generated in the Kanawha River Basin are shown in Table 12a. The Charleston industrial complex is largely within minor area G-2 and this area accounts for 42 percent of the total municipal base load generated within the basin. Minor area G-2 contributes 93 percent of the total industrial organic waste load generated in the Kanawha Basin.

Shown in Table 13a are the present and projected raw waste loads for the various minor areas. Raw waste loads are projected to increase on the average of 1.4 times by the year 1980, 1.9 times by 2000, and 2.9 times by 2020.

Water Quality Control Problems

Listed in Table 14a are the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures for pollution control. The raw waste loads are assumed to have received secondary treatment or equivalent reduction before discharge to the stream.

TABLE 14a

KANAWHA RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Kanawha River	Charleston 1/	G-2	X			
Piney Creek	Beckley 1/	G-5			X	
E.Fk. Greenbrier River	Durbin 1/	G-6	X			
Bluestone River	Bluefield 2/	G-8	X			
Peak Creek	Pulaski 2/	G-8		X		
Chestnut Creek	Galax 2/	G-8		X		
Buffalo Creek	W. Jefferson 3/	G-9		X		

1/ West Virginia
2/ Virginia
3/ North Carolina

TABLE 12a

KANAWHA RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*	
					Domestic & Commercial	Estimated Industrial
Area Designation G-1						
West Va.	Putnam	4	1,500	Kanawha River, Hurricane Creek	1,500	231,000
	Subtotal	4	1,500		1,500	231,000
Area Designation G-2						
West Va.	Kanawha	14	132,300	Kanawha River, Elk River, Coal R.	132,300	5,994,000
	Subtotal	14	132,300		132,300	5,994,000
Area Designation G-4						
West Va.	Braxton	2	1,880	Buffalo Creek, Elk River	1,880	1,100
"	Clay	1	300	Elk River	300	1,300
"	Roane	0				0
	Subtotal	3	2,180		2,180	2,400
Area Designation G-5						
West Va.	Boone	3	3,100	Little Coal River, Coal River	3,100	2,700
"	Fayette	8	13,330	Kanawha River, Creeks	13,300	5,400
"	Raleigh	5	19,940	Piney Creek, Little Whitestick Crk.	19,940	9,600
	Subtotal	16	36,370		36,370	17,700

TABLE 12a (cont'd)

KANAWHA RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*: Domestic & Commercial	Raw Waste Production Before Treatment Population Equivalent*: Estimated Industrial
Area Designation G-9						
North Carolina	Alleghany	1	1,000	Little River	1,000	200
"	Ashe	1	750	Buffalo Creek	750	2,600
"	Watauga	2	6,175	Boone Creek, New River	6,175	400
	Subtotal	4	7,925		7,925	3,200
Other Areas in Basin						
Virginia	Tazewell	2	6,315	Bluestone R., Laurel Fork Creek	6,315	0 1/
	Subtotal	2	6,315		6,315	0
	TOTAL	80	311,955		311,955	6,444,300

1/ - Included with Mercer County, West Virginia.

*NOT to be interpreted as waste loads to the stream.

TABLE 13a

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation G-1				
Domestic and Commercial	1,500	2,300	3,200	5,300
Industrial	231,000	520,000	988,800	2,069,700
Subtotal	232,500	522,300	992,000	2,075,000
Area Designation G-2				
Domestic and Commercial	132,300	188,000	280,500	400,000
Industrial	5,994,000	7,900,000	11,000,000	16,000,000
Subtotal	6,126,300	8,088,000	11,280,500	16,400,000
Area Designation G-4				
Domestic and Commercial	2,200	2,300	2,800	3,700
Industrial	2,400	3,900	7,300	12,400
Subtotal	4,600	6,200	10,100	16,100
Area Designation G-5				
Domestic and Commercial	36,400	38,200	46,600	65,500
Industrial	17,700	25,700	41,600	62,700
Subtotal	54,100	63,900	88,200	128,200

TABLE 13a (cont'd)

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Other Areas in Basin				
Domestic and Commercial	6,300	9,100	13,900	22,200
Industrial	0	2,000	3,800	7,000
Subtotal	6,300	11,100	17,700	29,200
Kanawha River Basin				
Domestic and Commercial Total	311,900	415,900	599,900	881,400
Industrial Total	6,444,300	8,774,500	12,525,500	18,950,700
GRAND TOTAL	6,756,200	9,190,400	13,125,400	19,832,100

*NOT to be interpreted as waste loads to the streams.

0

6

Ohio River Basin Comprehensive Survey.
Volume V. Appendix D.
Water Supply and Water Pollution Control.

11 1967

FRAMEWORK STUDY
OF
WATER SUPPLY AND WATER POLLUTION CONTROL
PROBLEM AREAS IN THE
OHIO RIVER BASIN

12 84p.

Prepared by

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI, OHIO

UNITED STATES
DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
Ohio Basin Region
4676 Columbia Parkway
Cincinnati, Ohio 45226

IN REPLYING ADDRESS:

June 19, 1967

Brig. General W. Roper
Division Engineer
U. S. Army Engineer Div., Ohio River
P. O. Box 1159
Cincinnati, Ohio 45201

Dear General Roper:

The Federal Water Pollution Control Administration is pleased to transmit the Framework Report on Water Supply and Water Quality Control Problem Areas of the Ohio River Basin, to be included as Appendix "D" in the Ohio River Basin Comprehensive Survey.

The Framework Study points out many problem areas in the basin where low flow regulation can abate the pollution situation; however, it must be remembered that this is only one solution to the problem. Treatment of wastes at the source is considered the principal approach to correcting pollution problems.

Much progress has been made in the immediate past to help the attack being made on water pollution that is not reflected in this report. During the 89th Congress three important pieces of water pollution control legislation were passed: the Water Resources Planning Act of 1965, the Water Quality Act of 1965, and the Clean Water Restoration Act of 1966. Present legislation provides the tools needed to make an effective water pollution control program. The primary task now is continued development of successful methods and institutions to use these tools.

Water quality standards are a key element in providing pollution control and should be closely tied in with other necessary program elements, such as research, planning and construction of facilities, at all levels of government.

The Framework Study can be utilized to point out the more immediate water quality problem areas of the basin and direct efforts of detailed study to these specific areas for solutions other than those outlined.

We appreciate the opportunity to have a part in the coordinated water resources study of the Ohio Basin.

Sincerely yours,

Richard A Vanderhoof

Richard A. Vanderhoof
Regional Director

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I INTRODUCTION

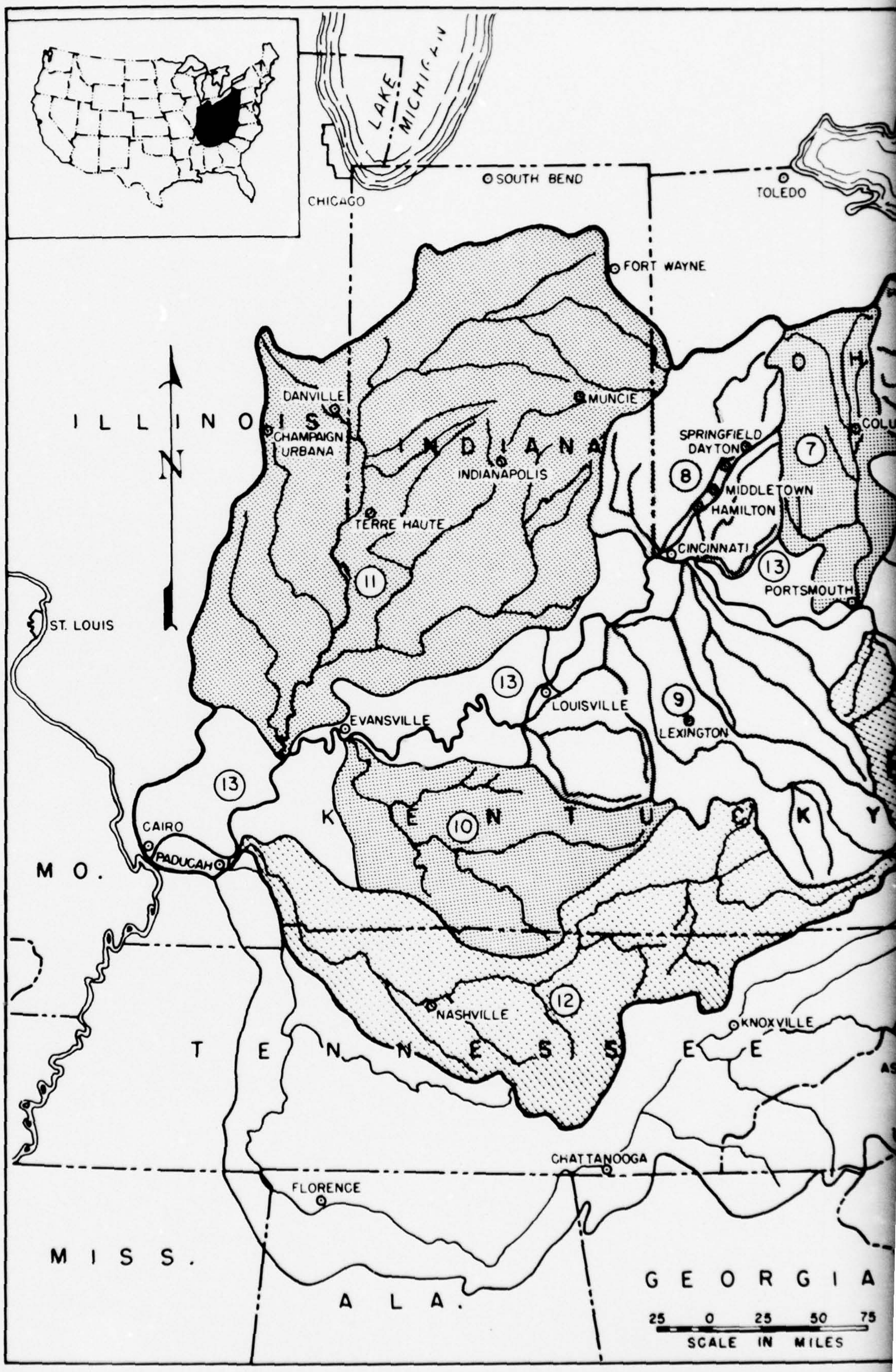
Congress has directed that a comprehensive plan be prepared for the development of water and related land resources of the Ohio River Basin. The plan requires an analysis of the basinwide needs for streamflow control and use of water for domestic, municipal, agricultural, and industrial water supply; water quality control; navigation; hydroelectric power; flood control and drainage; watershed protection and management; outdoor recreation; fish and wildlife conservation and other purposes. As one of the several Federal agencies actively participating in formulating the comprehensive plan, the Federal Water Pollution Control Administration was assigned to make a general appraisal of water needs for municipal and industrial water supply and water quality control.

The FWPCA study is oriented to water resources development and deals primarily with the use of the water resources of the Ohio River Basin as sources of supply and water quality control. Corrective measures other than flow regulation will be of utmost importance in the basin, especially in headwater or other water short areas. Detailed analyses of the other corrective measures for quality control beyond secondary treatment is not a part of the Comprehensive Survey of the Water and Related Land Resources of the Basin and are not described herein.

Streamflow regulation for quality control is a partial and interim solution in areas where waste-loadings approach or exceed stream assimilation capacity under existing low flow conditions after secondary treatment or equivalent waste reducing processes are applied.

Thirteen subbasin areas are reported separately as shown in Figure 1. Streamflows given in these reports are those estimated to be necessary to assimilate the residual organic wastes remaining in the effluent after secondary treatment or equivalent waste reduction processes are applied to wastes entering the stream from the designated areas.

Future municipal and industrial water supply and water quality control needs are based on population and industrial growth as forecast in the Projective Economic Study of the Ohio River Basin, designated Appendix B of the Comprehensive Survey. Appendix C, Hydrology; Appendix E, Groundwater and Appendix F, Agriculture contain additional data on the availability of water resources in the basin to meet projected needs.



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DANVILLE
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INDIANAPOLIS
TERRE HAUTE
SPRINGFIELD
DAYTON
MIDDLETOWN
HAMILTON
CINCINNATI
PORTSMOUTH
ST. LOUIS
EVANSVILLE
LOUISVILLE
LEXINGTON
CAIRO
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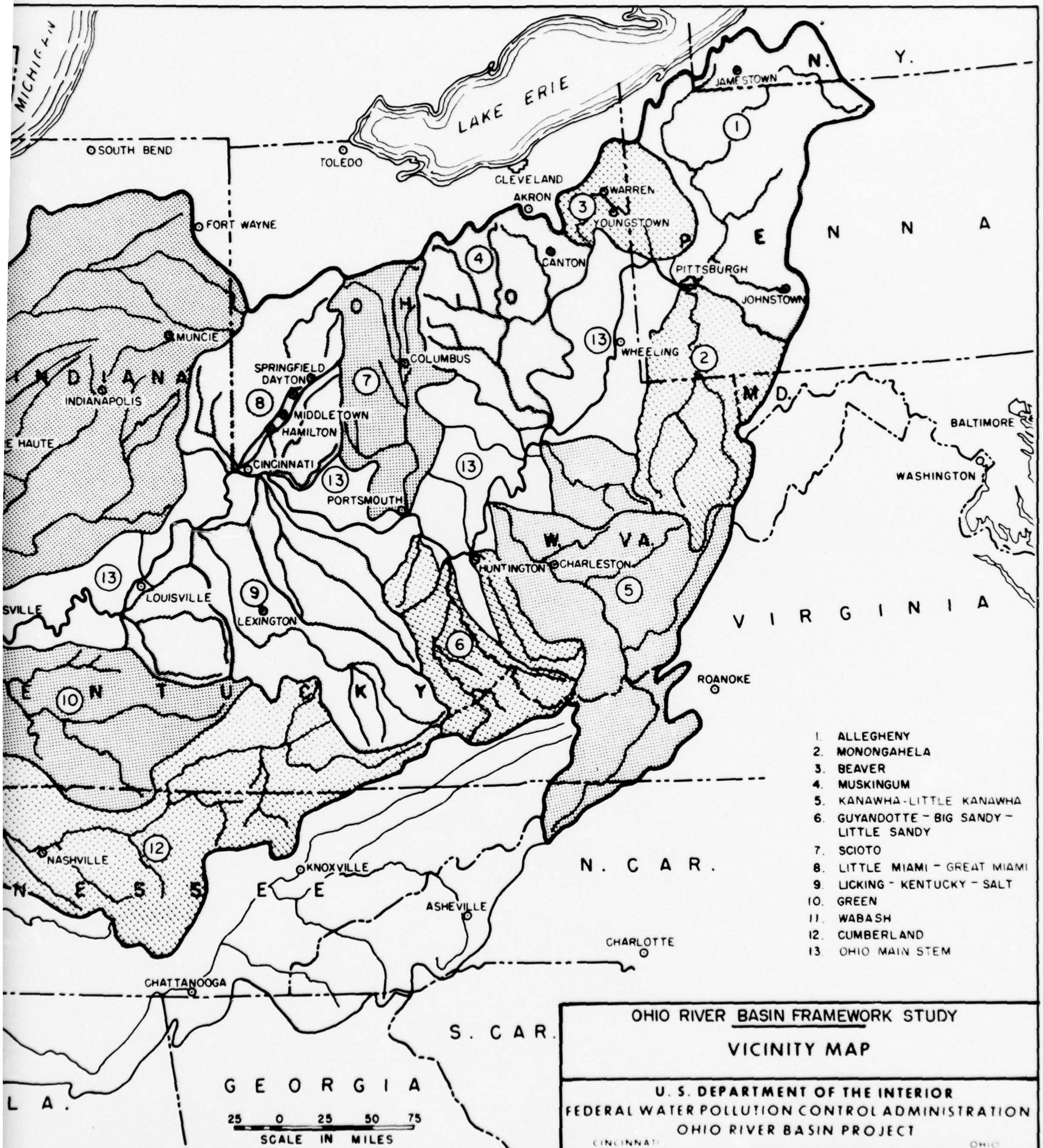
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TOLEDO
CLEVELAND
AKRON
WARREN
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CANTON
PITTSBURGH
JOHNSTOWN
P E N N A
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MUNCIE
COLUMBUS
WHEELING
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KNOXVILLE
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ASHEVILLE
CHARLOTTE
CHATTANOOGA
S. CAR.
GEORGIA
ALA.
1. ALLEGHENY
2. MONONGAHELA
3. BEAVER
4. MUSKINGUM
5. KANAWHA-LITTLE KANAWHA
6. GUYANDOTTE - BIG SANDY - LITTLE SANDY
7. SCIOTO
8. LITTLE MIAMI - GREAT MIAMI
9. LICKING - KENTUCKY - SALT
10. GREEN
11. WABASH
12. CUMBERLAND
13. OHIO MAIN STEM
25 0 25 50 75
SCALE IN MILES
OHIO RIVER BASIN FRAMEWORK STUDY
VICINITY MAP
U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 1

Authority

In a letter dated July 7, 1960, the Division Engineer, U. S. Army Engineer Division, Cincinnati, Ohio, requested that the Public Health Service* prepare a report on water supply and pollution control aspects of water resources development in the Ohio River Basin. This letter stated in part:

> "Pursuant to a resolution adopted on May 16, 1955 by the Public Works Committee, United States Senate, the Corps of Engineers is conducting a study on review of prior reports on the Ohio River with a view to determining whether any modification in the present comprehensive plan for flood control and other purposes in the Ohio River Basin is advisable.
>
> As a part of this study it will be necessary to investigate and evaluate needs for water supply, low-flow regulation and pollution abatement in order to determine how these needs may be met in conjunction with water resources developments for flood control and other purposes. This letter is to request that your Agency assist us in this phase of the study."

The original intent of the investigation was changed in 1963 from a review of reports to a Type 1 Basin Comprehensive Survey, of which the scope and objectives are defined in subsequent sections. This change is in accord with Guidelines for Framework Studies issued February 10, 1964 and revised June 10, 1965 by the Interdepartmental Staff Committee, Water Resources Council set up to assure that participation of the four Departments (Agriculture, Army, Interior and Health, Education and Welfare) in the Comprehensive Basin Planning Program is accomplished in an orderly, efficient, and coordinated manner.

Purpose and Scope

This Federal Water Pollution Control Administration, Framework Study of Water Supply and Water Pollution Control problem areas in the Ohio River Basin appears as Appendix D to the Ohio River Basin Comprehensive Survey. It is one of a series of cooperating agency reports coordinated by the Ohio River Division Corps of Engineers to form a broad scale analysis of water and related land resources development of the basin to meet foreseeable short- and long-term needs. → next page

*Responsibility for this investigation was transferred to the Federal Water Pollution Control Administration by the Water Quality Act of 1965 (PL 89-234). The FWPCA was transferred to the Department of the Interior on May 10, 1966 by Reorganization Plan No. 2 of 1965.

The objectives are the determination of overall basin water requirements for municipal and industrial water supply and water quality control and give general appraisals of the probable nature, extent, time of occurrence and possible measures to meet the indicated needs. As a water resources report, the purpose here is to show the possible effect that the available water resources in the area could have on the water supply and quality control demands generated in this basin. This approach is not intended to preclude other solutions to the problem of water quality control such as advanced waste treatment, holding ponds, deep well disposal, or other means that may be indicated in more detailed analysis of specific problem areas. The intent is to focus on the utilization of the available water resources to alleviate problem areas that may be anticipated during low flow periods after secondary treatment or equivalent waste reduction processes are applied.

The entire Ohio River Basin, exclusive of the Tennessee River, comprises the area under study. It includes the major portions of the State of Ohio, Indiana, Kentucky, and West Virginia; substantial parts of Pennsylvania, Illinois, and Tennessee; and smaller areas of New York, Maryland, Virginia, and North Carolina.

Data on present water use, current waste loads, existing water quality and hydrology have been derived from available sources; no field surveys providing original data were made in connection with this study.

The Projective Economic Study of the Ohio River Basin was used as the basis upon which to appraise future growth of large subregions in relation to water requirements for municipal and industrial purposes and the magnitude of resulting waste loads from such human activity. The economic study set quantitative bench marks or guides for 19 subregions by county delineation grouping that most nearly represented the economic activity of the major tributaries and main stem basin drainage areas. The ecomomists of the Corps of Engineers and the FWPCA worked together to disaggregate the 19 subregions into 61 smaller areas.

Projections of the three New York counties omitted from the original Projective Economic Study were added to the above disaggregation to make a total of 62 study areas for which population and economic activity guides were provided.

Overall needs for municipal and industrial water supplies and waste loads generated for the years 1980, 2000 and 2020 were determined for each of the 62 areas based on the above population and economic study results.

Total municipal-industrial water supply needs for each of the 62 minor areas were compared with the known dependable water supply in the study areas to provide a basis for recognition of present and future problems.

Only the larger local water supply problems in a minor area are described. The relative magnitude of the major problems varies by subbasin and it was necessary to go to greater detail in some basins.

Pollutional loads generated in each minor area were quantified in terms of population equivalents in first stage ultimate biochemical oxygen demand.

The waste loads generated were assumed to be reduced by secondary or equivalent treatment in all cases before discharge to the stream.

All low flow quality problem areas were identified even though some of the areas are so located that flow regulation may not be feasible. This method appears to have the advantage of comparing magnitudes of water quality control problems and indicating specific areas where flow regulation, improved waste treatment, or other methods of waste disposal must be developed.

Water quality problems other than organic such as acid mine drainage, brine pollution, heat, taste and odors, and nutrient are described in each subbasin where the problem occurs.

Acknowledgement

The Ohio River Division Engineer, Corps of Engineers, U. S. Army, has supplied considerable data used in the study such as minimum flows of selected frequencies, time of streamflow between waste load points, and flow regulation capabilities of existing reservoirs. In addition, the study of demographic-economic trends and forecasts of future growth in the basin prepared for them by the A. D. Little Company have been made available for FWPCA use. Extensive use has been made of streamflow, water quality and ground water availability observations of the U. S. Geological Survey. Free exchange of working data and preliminary drafts of the cooperating agencies have aided and expedited the completion of this report.

The Departments of Health, Economic Development and Natural Resources in each of the State governments within the basin have been available sources of background data. The Coordinating Committee of State officials and participating government agencies formed by the Corps of Engineers has provided continued cooperation and helpful direction in the completion of the study.

II METHOD OF INVESTIGATION

ECONOMIC BASE STUDY DISAGGREGATION

The demand for water in an area and the waste loads which are produced depend on the population and type and amount of economic activity in the area. In order to have a base against which to relate current water requirements and waste loads and projections of future population and economic activity from which to estimate future water requirements and waste loads, a projective economic base study is essential. Such a study characterizes the current economic situation, examines the economic forces and relationships which indicate future changes, and quantifies the expected changes.

In March 1962 the Arthur D. Little Company of Cambridge, Massachusetts, was commissioned by the Corps of Engineers to provide an analysis and projection of the economic activity in the Ohio River Basin and its component subbasins over a period of 50 years. That study was completed in August 1964 and published as Volume III (Appendix B) of the Ohio River Basin Comprehensive Survey, Appendix B, Projective Economic Study, U. S. Army Engineer Division, Ohio River Division, Cincinnati, Ohio.

The region included in the Projective Economic Study (PES) is the area of the Ohio River Drainage Basin, except for the Tennessee River tributary basin, with the approximate boundary determined by county boundaries for purposes of data availability. The economy of the basin was related to the economy of the Nation, and in turn 19 subbasin delineations were related to the entire basin. The items of particular study interest were industrial output, employment, and population. Results of the Projective Economic Study set quantitative bench marks for the 19 subbasins, each consisting of county groupings that most nearly represented the drainage area. The results were made available to all agencies cooperating in the Framework Study.

Methodology

The methodological framework used in the Projective Economic Study consists of two distinct parts. The first part is an econometric model based on input-output technique which generated projections for output measured in 1960 constant dollars, employment, and population.

The second part consists of an allocation procedure used to distribute shares of the Ohio River Basin projection among the 19 subareas of this basin. The change in procedure was due to the lack of data for adaption of the Ohio River Basin model to the subareas.

Projections of future economic activity should never be considered to be levels which must inevitably occur in the future, but rather a forecast of what is believed most likely to occur if the underlying assumptions of the study, both implicit and explicit, were to occur. This study was designed to be as realistic as possible; however, changes will occur which are impossible to foresee, and the lack of sufficient historical data makes it impossible to realize the full potential of the methodology employed.

The basic assumptions of the Projective Economic Study were: no major depressiors or wars, a high level of national employment and economic activity, and a continuation of the current relative needs of the civilian economy and the national defense.

Two additional assumptions warrant special comment. They are: (1) the assumed validity of extending into the future a long-term historic national growth trend, and (2) the assumed timely availability of water in sufficient quantity and quality to support the projected economy.

The historical growth trend is slower than that used in other recent national projections. A higher rate has been used in the more recent studies in the belief that it is attainable and also that it is necessary to maintain an improving standard of living. The assumed slower growth rate in the A. D. Little Study does not invalidate the study for the uses for which it was designed, namely to determine problem areas for later more detailed study.

Small Area Projections

In order to utilize the projections from the Arthur D. Little Projective Economic Study in the estimation of water requirements and waste loads which could be related to stream segments, it was necessary to disaggregate the subarea projections into projections for smaller areas. The 19 subareas were subdivided into 61 "small areas" (see Figure 2) on the basis of criteria which (1) attempted to maintain economic unity within the small areas, and (2) approximate

minor drainage basins. Projections for the small areas were made by disaggregating the projections for each of the subareas into its component small areas on the basis of past and expected trends in the relationship between the small area and the study areas.

The projection technique used is an extension of the proportional and differential shift analysis[1] and takes the form of the following equation which is applied to each of the commodity industries.

$$E^R_{t3} = E^R_{t2}\,\frac{E^B_{t3}}{E^B_{t2}} + (E^B_{t3} - E^B_{t2})\,\frac{E^R_{t2} - \dfrac{E^B_{t2}\;E^R_{t1}}{E^B_{t1}}}{E^B_{t2} - E^B_{t1}}$$

Where:

E^R = Small area employment in the particular industry

E^B = Subarea employment in the industry

t1 = Initial analytical date

t2 = Second analytical date

t3 = Projected date

The results of the application of this formula were subjected to judgmental changes, where it is expected that factors affecting the future changes of the industry in the region will differ in character or magnitude from those affecting past changes.

Service industry projections were made by distributing the projected employment for the subarea to the small areas on the basis of total commodity employment in each area.

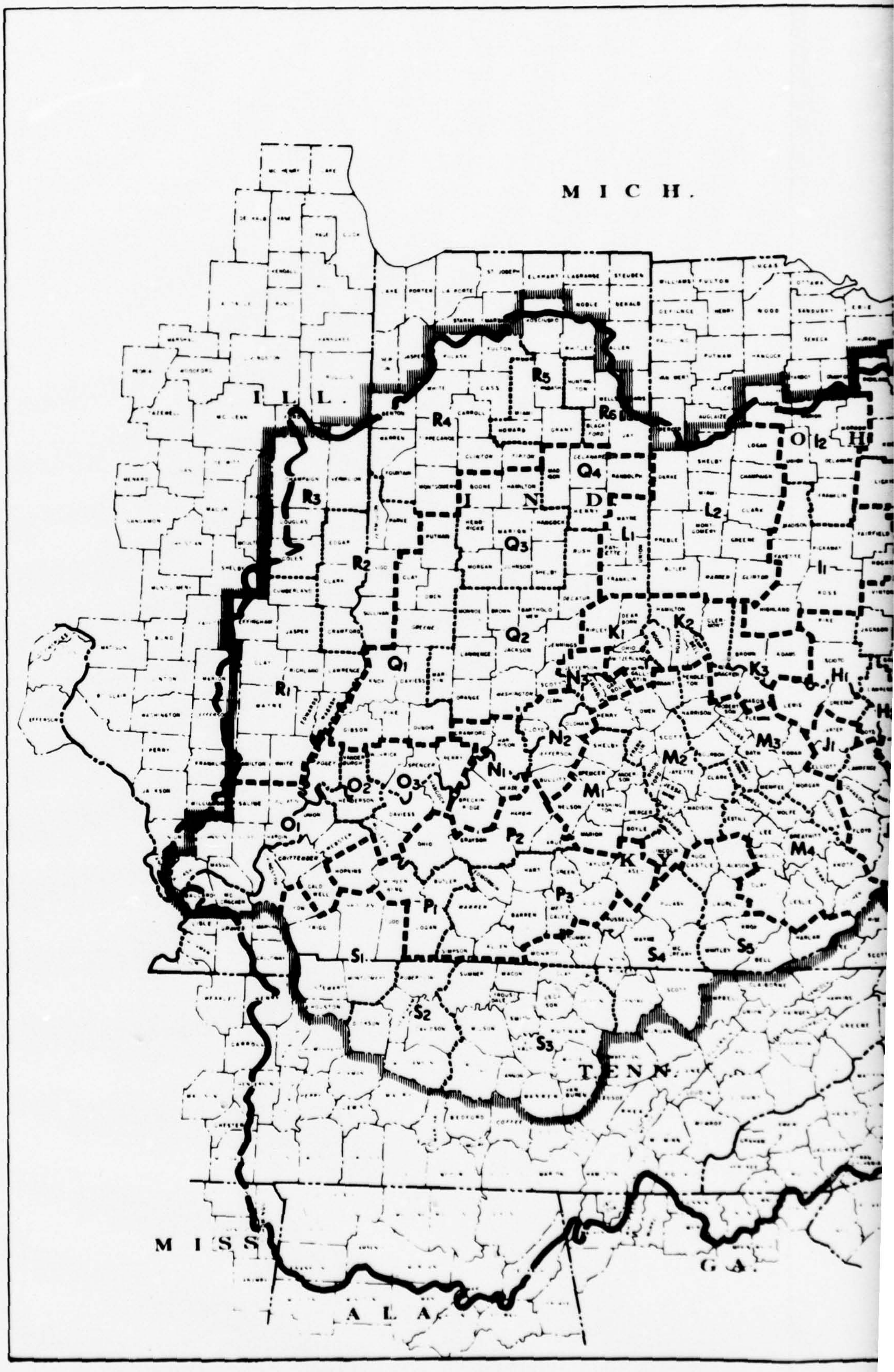
Population for the small areas was projected by assuming that the participation rate in the small area would gradually converge toward the participation rate for the basin as a whole with the two becoming equal in 2010.

1/ "Regions, Resources, and Economic Growth." Perloff, Harvey S., Dunn, Edgar S., et al., John Hopkins Press, 1960, p.71.

Indices of output for each two digit SIC[1] industry category in each small area were calculated by multiplying projected employment by the productivity per employee for the corresponding category derived from the Projective Economic Study. The indices are expressed in terms of 1960=100.

Total populations from the smaller area breakdowns are coupled with the urban population projections from the Projective Economic Study to project a future population served for municipal water supplies and waste loadings. Manufacturing employment and output indices are utilized to project industrial water use and waste loadings. The economic quantitative information used in this report appears in each subbasin section.

1/ Standard Industrial Classification



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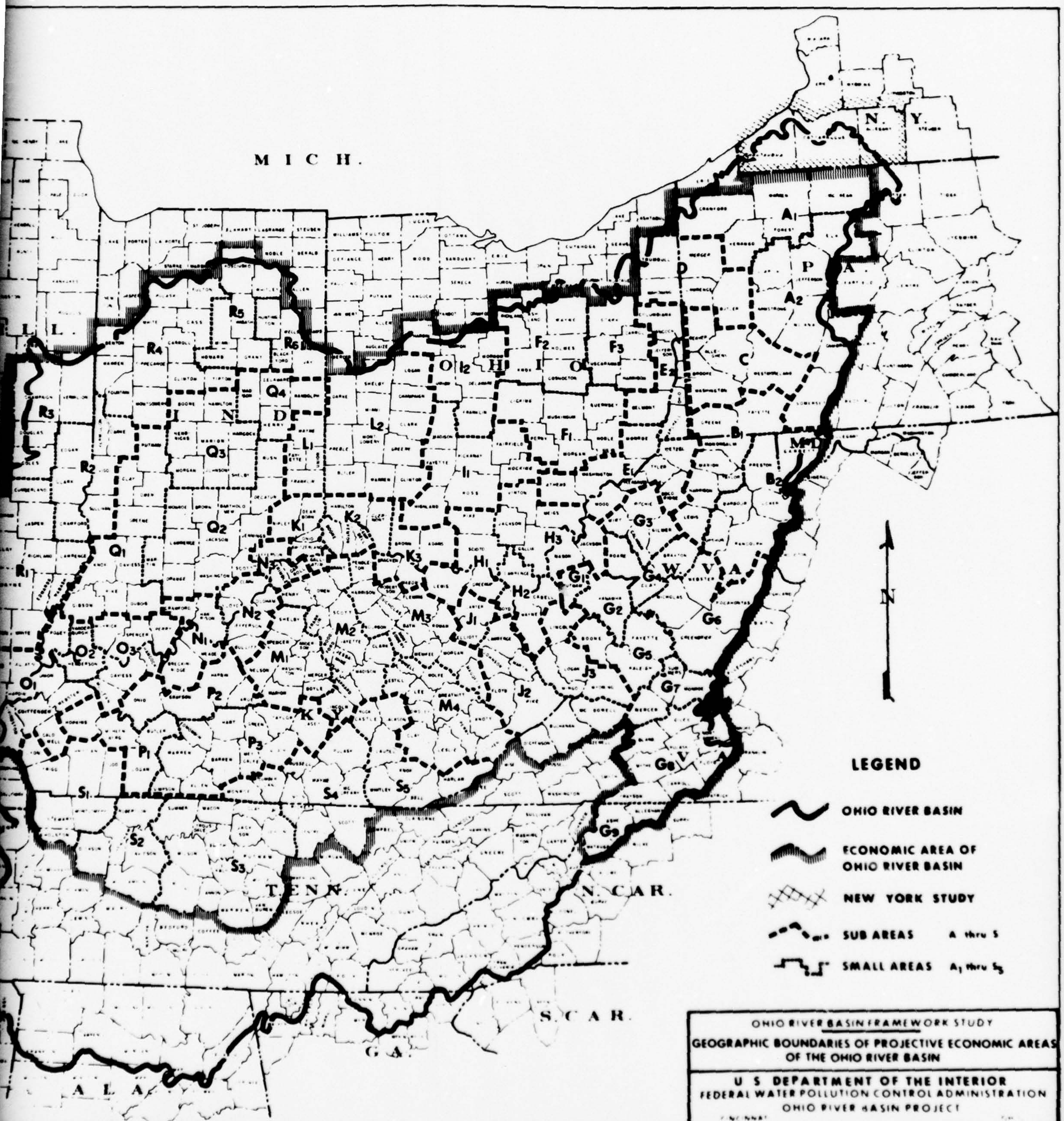
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LEGEND
OHIO RIVER BASIN
ECONOMIC AREA OF OHIO RIVER BASIN
NEW YORK STUDY
SUB AREAS A thru S
SMALL AREAS A1 thru S5
OHIO RIVER BASIN FRAMEWORK STUDY
GEOGRAPHIC BOUNDARIES OF PROJECTIVE ECONOMIC AREAS OF THE OHIO RIVER BASIN
U S DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT

FIGURE 2

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Municipal Water Supply Rationale

The demand for municipal water supply is created by a number of special uses; i.e., domestic, commercial, public, fire, and industrial. The size of the community, its location, number and diversity of commercial business establishments, community habits, availability, quality and cost of water, existence of sewers, public policy with respect to civic duties and size and type of industries within any city are characteristics peculiar to that city under consideration only. As a consequence, the municipal water demand computed on a per capita basis can be expected to vary among cities. Municipal use is largely nonconsumptive and it can be expected that about 90 percent of the water used for municipal purposes will be returned to the water courses.

For purposes of developing overall data on municipal water demand, writers have grouped cities by population brackets to determine water use. This method furnishes a general idea of the overall quantity of municipal water demand that is deemed sufficient for the Framework Study of the Ohio River Basin.

Porges[1/] has broken down per capita consumption figures by population groups as follows:

Population Group	U. S. Average Demand 1948	gpcd 1954
500-1,000	100	
1,000-5,000	108	
5,000-10,000	114	129
10,000-25,000	123	134
25,000-50,000	127	133
50,000-100,000	121	129
over 100,000	157	150

1/ "Factors Influencing Per Capita Water Consumption," Ralph Porges, Water and Sewage Works, 1957.

Porges further reported[1] that for an average output of 149 gallons per capita daily (gpcd), the distribution of water was as follows:

Use	1954 gpcd	1954 Percent	1958 Percent
Domestic	64	42.8	41
Commercial	28	18.9	18
Industrial	37	24.9	24
Public & Other	20	13.4	17
Total	149	100.0	100

The above tabulation also shows a distribution of municipal water use made from an analysis of 1958 Public Health Service inventory of public water supplies. This analysis included 580 communities serving 83,704,000 people. Communities with less than 100,000 population averaged 132 gpcd, while the group with a population greater than 100,000, averaged 150 gpcd, which compares closely with the use rate found in the earlier survey for these size categories.

The State of Ohio Department of Natural Resources reported[2] on results of an extensive study of municipal water supplies. Comparing the per capita use figures for the various population categories, the figures for Ohio are somewhat lower than the U. S. figures in the previous tabulation. The distribution by types of use reported for Ohio closely approximated those given by Porges above.

Variations among municipalities and stream sections are accounted for in the inventory of present water supply uses. This inventory reflects local choices as to sources of supply and quality, available quantities of water, average per capita use rates, and willingness and capability to pay for water supply source systems. The present municipal uses were tabulated by county and a municipal water use base arrived at for each county. From this base, the future municipal water needs were estimated using average per capita use figures and population projections for the area.

1/ "1954 Vital Statistics of Water Statistics," Ralph Porges, Water Works Engineering, February 1957.

2/ "Municipal Water Supply in Ohio 1955 and 1957." Anthony R. Rudnick, Report No. 9 Ohio Water Plan Inventory, State of Ohio - Department of Natural Resources - Division of Water, July 1962.

Medium-range projections[1] for those States that have large land areas in the study area are shown below:

	Per Capita Water Use (g.p.d.)			
	1954[1]	1960[2]	1980[1]	2000[1]
Ohio	149	138	147	147
Indiana	155	126	151	151
West Virginia	112	99	127	132
Kentucky	125	138	131	136
Pennsylvania	147	144	154	154
Average	138	129	142	144

Included also in the above tabulation are the 1960 water use figures for public supplies presented by MacKichan and Kammerer[2] for these States.

These medium projection trends show only a slight increase in per capita water use for the various States in the basin; however, these are average figures and tend to be less than the gpcd figure for municipalities with a population greater than 100,000.

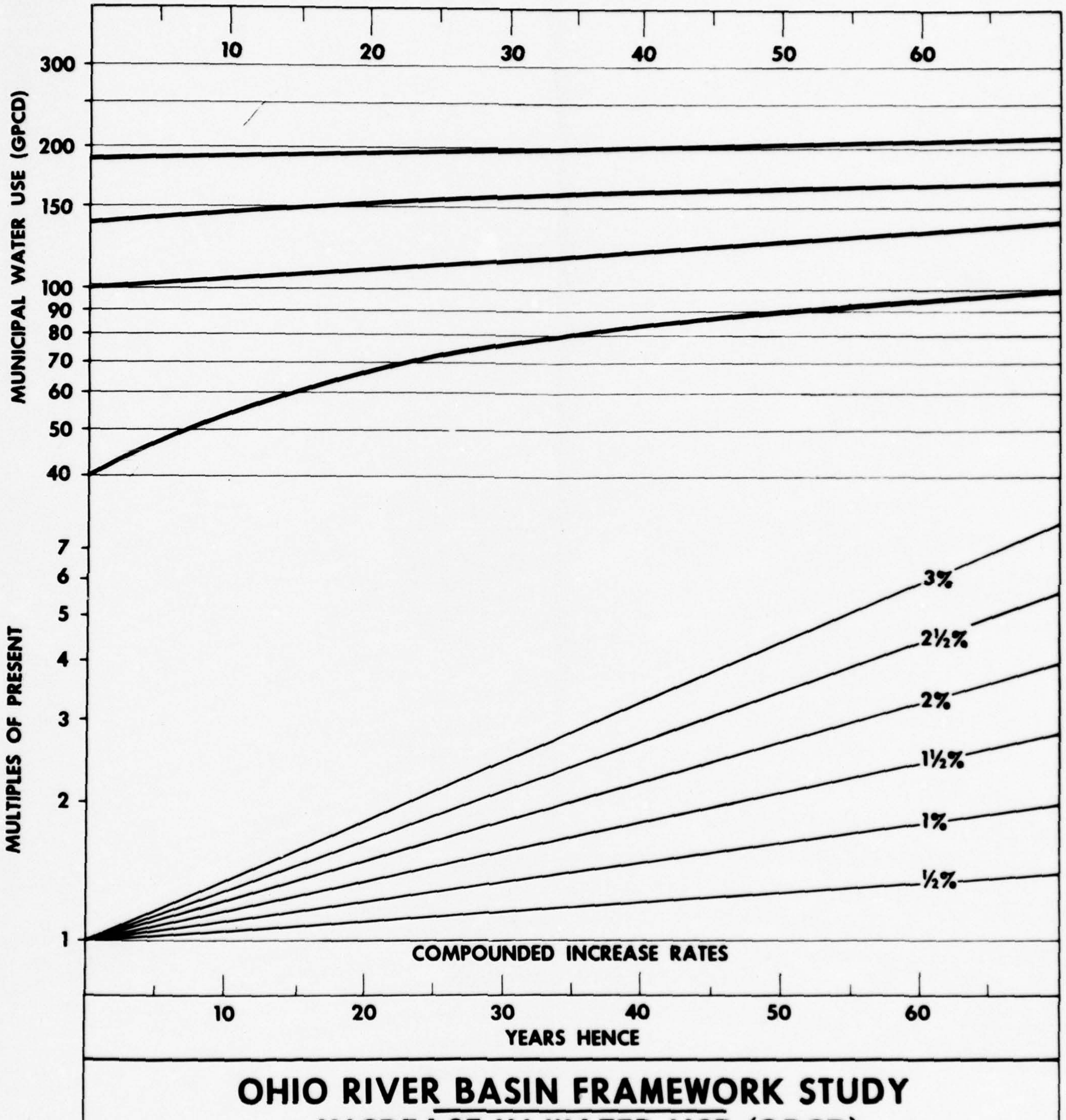
For purposes of this study, it is considered reasonable for the 50,000 to 100,000 population group to expect an average use of about 135 gpcd. For communities presently using less than this amount a rapid increase is expected. Figure 3 depicts the increase in unit water use for municipal systems utilized for purposes of this study. The rate of increase is about three percent compounded if present water use is 40 gpcd, tapering off to about one percent at 80 gpcd, and to about one-half percent when 150 gpcd is reached.

Industrial Water Supply Rationale

Industrial water requirements are complicated by many factors and hence display great variability. Every product requiring water in its manufacture utilizes differing quantities and qualities of water and even the manufacture of identical products differ in amounts of water used, depending on the processes involved. The prime uses of water in industry are for cooling or condensing, and for product processing.

1/ Water Resources Activities in the U. S. Future Requirements for Municipal Use, Select Committee Print No. 7. 86th Congress. January 1960.

2/ Estimated Use of Water in the U. S., 1960 Geological Survey Circular 456. K. A. MacKichan and J. C. Kammerer, 1961.



OHIO RIVER BASIN FRAMEWORK STUDY
INCREASE IN WATER USE (GPCD)

U. S. DEPARTMENT OF THE INTERIOR

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

OHIO RIVER BASIN PROJECT

CINCINNATI OHIO

FIGURE 3

Industrial water use has been computed in general terms on a daily use per employee or per unit production basis. The Bureau of Census 1/ has collected water use figures for various regions in the United States for the four-digit industrial categories. The figures presented in the Census reports were statistically analyzed in a recent study 2/ and the conclusion reached that either employment or value added by manufacture could be used in estimating industrial water use in most cases. In a few cases no significant correlation could be demonstrated to exist.

The Ohio Department of Natural Resources 3/ has carried on an extensive study of industrial water use in Ohio. Table 1 shows water use figures per industrial employee for the 2 digit SIC 4/ categories and range of variability among the 4 digit categories derived from this report. Table 2 shows the distribution of water use by 2 digit industrial categories and distribution between source and use as derived from the Census of Manufacturing for the Ohio Region.

For purposes of the Framework Study it was concluded that a reasonable approximation of industrial water use could be made by tabulating the manufacturing industries by SIC codes within each county and assigning a total water intake per employee derived from the previously mentioned sources.

Present Municipal and Industrial Water Use

A base, or present, municipal water use for each minor economic area in the particular subbasin was obtained by arraying data contained in the Public Health Service Inventory of Municipal Water Facilities by county for the area in the Ohio River drainage basin.

1/ U. S. Bureau of Census. U. S. Census of Manufacturers: 1958 Industrial Water Use Subject Report MC58 (1)-11
U. S. Bureau of Census. 1954 Census of Manufacturers Industrial Water Use Supplement - Bulletin MC-209.

2/ "Industrial Water Use," by Willis G. Eichberger, U. S. Department of Health, Education and Welfare - Public Health Service (For Administrative Use Only).

3/ "Industrial Water Use in Ohio," Anthony R. Rudnick, Report No. 8 Ohio Water Plan Inventory 1960, State of Ohio Department of Natural Resources - Division of Water.

4/ Standard Industrial Classification.

Total water use and population served were determined for those supplies that had their source in each of the subbasins. An average gallons per capita daily (gpcd) usage was computed for each minor economic area in this manner.

Industrial water usage was obtained by arraying the manufacturing industries within each county by SIC codes and number of employees. To each of these industries an average water use per employee per day figure was applied to compute a reasonable water use for each industry in the county. The indicated water use for those industries lying within the subbasin boundaries were totaled as the approximation of the industrial water use for the subbasin.

Realizing that some of this industrial water is supplied through municipal sources and included in the municipal water use figures, an average figure of 70 gpcd was deemed reasonable to represent domestic and commercial use within the central systems and, where the water use from central systems exceeds this figure, the difference was subtracted from the industrial water use. In areas where more detailed information exist in the files or published form, it was used to modify the industrial water use computation as described in the preceeding paragraph.

Table 9 in each of the subbasin reports presents the summary of the base municipal and industrial water use and the primary sources of supply by minor economic areas.

Since the economic boundaries which were delineated by county groupings and the subbasin drainage area did not necessarily coincide, it was necessary to summarize other water supplies contained in the basin to complete a total water use picture for the subbasin. These are also shown in Table 9 of the subbasin reports with the counties and minor economic areas in which they are found. Water use is then summarized for the basin.

Projected Municipal and Industrial Water Requirements

The present population served by central water supplies for each subbasin economic minor area as shown in Table 9 of the subbasin reports is assumed to increase at least at the same rate as the total population for each minor economic area as shown in Table 6 in each of the subbasin reports. An additional increase in population served is expected due to greater urbanization. The increase factor due to urbanization was determined by dividing the basin urban population index by the basin total population index. This factor was then used to adjust the population served for each minor economic area in the subbasin.

The population served for the "other" supplies was projected by using the economic area projections listed with each or modified by judgment factors where deemed necessary. In all cases, the projected population served by central supplies for the time periods 1980, 2000 and 2020 is shown in Table 10 in each of the subbasin reports.

The estimated increase in the gallon per capita daily usage from the base figure for each time period is included in the table and applied to the population served to quantify water use from municipal systems for each time period.

Industrial water usage is projected by utilizing the manufacturing employment and output indexes given in Table 7 in each of the subbasin reports for each economic minor area. Increased productivity per employee due to technological development and mechanization has given rise to an increased water use per employee. On the other hand, certain technological changes and the increase of water recirculation tends to decrease the water use per unit of output. In some areas of the basin, employment is shown to rise only slightly or to decrease, whereas the output from industry is rapidly rising. To determine the effect of increased productivity and technological changes on water use requires detailed studies beyond the scope of the Framework Study.

Considering the many factors involved, it is concluded that future industrial water use probably lies in the area between the values based on projected indexes for output and employment. For purposes of this study the average of the two indexes are used to project industrial water requirements.

Table 10 in each subbasin report summarizes the projected municipal and industrial water requirements by minor economic areas and by subbasin.

Water Supply Problems

Table 10 in each subbasin report shows the projected municipal and industrial water use for minor economic and "other" areas. The distribution of this use within minor economic areaswas examined to determine where major water shortages might exist now or be expected to occur in the future.

Projected water supply requirements were compared to the 1 day low flow occurring once in 30 years[1] and the available ground water[2] to determine if the needs could be met with available sources. Areas where requirements exceeded available sources were designated problem areas. These problem areas are given in Table 11 of each subbasin report and possible solutions are discussed.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 1

INDUSTRIAL WATER USE PER EMPLOYEE IN OHIO
(365 day year basis)

SIC* CODE	Industry	Av. use, 2 digit SIC gal/emp/day	Water use range 4 digit SIC gal/emp/day
19	Ordnance	100	-
20	Food and Kindred Products	700	100-8,200
21	Tobacco Manufacturing	60	30-100
22	Textile Mill Products	600	10-2,500
23	Apparel and Related Products	40	20-80
24	Lumber and Wood Products	80	10-100
25	Furniture and Fixtures	200	30-300
26	Paper and Allied Products	2,200	100-7,500
27	Printing and Publishing	200	40-400
28	Chemical and Allied Products	9,100	20-31,400
29	Products of Petroleum and Coal	8,900	300-27,800
30	Rubber Products	1,300	10-5,200
31	Leather and Leather Products	100	30-900
32	Stone, Clay and Glass Products	1,200	30-10,200
33	Primary Metals Industries	14,500	50-123,000
34	Fabricated Metal Products	1,900	100-10,900
35	Machinery, except Electrical	300	100-400
36	Electrical Machinery	200	100-400
37	Transportation Equipment	300	100-1,100
38	Instruments and Related Products	100	50-100
39	Misc. Manufacturing Industries	300	10-700
	State	2,900	10-123,000

*Standard Industrial Classification Code.

TABLE 2

INDUSTRIAL WATER USE BY SOURCE

SIC Code	Industry	(1) Water Use Per 1000 Emp. mgd	(2) Sources: Public (%)	Company Surface (%)	Company GD (%)	(3) Uses: Process (%)	Cooling (%)	Boiler and Sanitary (%)
33	Primary Metal Industry	14.70	8	89	3	21.8	72.3	5.9
28	Chemical & Allied Prod.	9.40	9	64	27	11.0	81.8	7.2
29	Petroleum & Coal Prod.	9.03	13	76	11	10.6	80.5	8.9
26	Pulp, Paper & Products	2.51	14	68	18	68.9	20.2	10.9
34	Fabricated Metal Products	2.05	90	3	7	23.5	47.4	29.1
30	Rubber Products	1.43	40	45	15	11.5	58.4	30.1
32	Stone, Clay & Glass Products	1.26	10	81	9	21.4	60.2	18.4
20	Food and Kindred Products	.95	40	24	42	25.8	62.9	11.3
22	Textile Mill Products	.75	17	40	43	68.9	10.9	20.2
37	Transportation Equipment	.39	67	23	10	27.3	43.5	29.2
39	Miscellaneous	.38	46	26	28	35.6	27.1	37.3
35	Machinery Except Electrical	.36	50	31	19	33.3	26.7	40.0
31	Leather and Leather Goods	.27	63	21	16	70.0	10.0	20.0
36	Electrical Industrial App.	.25	66	27	7	20.4	36.4	43.2
25	Furniture and Fixtures	.24	43	57	-	42.8	42.8	14.4
27	Printing and Publishing	.23	93	7	-	23.1	38.5	38.4
38	Instruments	.17	26	53	21	36.8	42.1	21.1
24	Lumber and Wood Products	.12	9	76	15	17.3	39.8	42.9
23	Apparel and Related Products	.06	100	-	-	33.0	33.0	33.0
21	Tobacco Manufacturing	.09	100	-	-	25.6	49.6	24.8

(1) "Industrial Water Use in Ohio", Department of Natural Resources, December 1960.

(2), (3) Developed from Table 4, 1954 Bureau of Census of Manufacturing.

WATER QUALITY CONTROL

Municipal and Industrial Waste Loads

The strength of municipal sewage may be described in terms of any of several characteristics, the most important of which are: solids (both suspended and dissolved), biochemical oxygen demanding (BOD) or chemical oxygen demanding (COD) organic materials, bacteria, nutrients, and toxic materials. The amounts of these various materials to be expected in sewage effluent will vary greatly depending on the degree of treatment and character of the sewage. The main factors affecting the character of municipal sewage are: type of sewer system (combined or separated), infiltration, industrial wastes discharged to municipal sewers, temperature and age of sewage.

Treatment of sewage at this time involves the removal of settleable and floating solids from the waste flow (primary treatment), subsequent biological treatment of primary effluent for reduction of soluble and suspended organic matter (secondary treatment) and chlorination for reduction of bacterial numbers.

The BOD of waste effluents is usually the most objectionable characteristic from a water pollution standpoint and its reduction is one of the primary aims of sewage treatment processes. Organic pollution and its effects on the oxygen balance of the stream has been selected as the controlling factor in maintaining water quality in the stream to quantify required streamflows.

The biological stabilization of the organic material in receiving waters utilizes oxygen which is obtained from that available in the receiving water. Reduction of the oxygen content of natural waters reduces their suitability as an environment for the higher forms of aquatic life. Reduction to a very low level would prevent any fish life and give rise to odors and other undesirable conditions. Reduction of waste effluent carbonaceous BOD by the practical common methods of treatment has been carried on to a high degree. With well designed and operated treatment facilities removals of 95 percent can be achieved.

Pollutional characteristics of industrial wastes are so varied it is not possible to establish a quantitative measure of industrial waste discharge that covers all factors, although partial evaluation can be made with respect to specific characteristics. A major factor in pollution by industrial waste as well as by municipal sewage is the quantity of organic matter discharged, and since much of this material is oxidized by chemical and bacterial action treatment processes, removal is much the same as for municipal wastes.

The quantity of industrial organic contamination has been reported by comparison with domestic sewage on the basis of population equivalent (P.E.). Population equivalent should be clearly understood in this report as referring to only oxidizable organic material as the waste; it does not take into account other pollutional characteristics that may be of equal or greater significance. A different type of P.E. has occasionally been used, based on suspended solids load; population equivalents are also possible with respect to chlorine demand, total volume or certain other characteristics. Such factors as toxicity, however, cannot be described by comparison with domestic sewage.

The following tabulation gives an indication of comparison between some industrial wastes and municipal sewage by population equivalent.

Oxygen Demand & Suspended Solids of Waste Produced per Employee of Each Industry as Compared with Domestic Sewage (Sewage = 1)[1/]

Industry	Oxygen Demand	Suspended Solids
Tannery	25.3	12.0
Chemical Manufacturing	22.5	7.4
Organic Waste	2.9	2.4
Mill Pickling	3.6	3.8
Dye Wastes	44.2	5.4
Laundry	22.8	22.2
Distillery	470.0	181.0
Dairy	44.6	5.7
Miscellaneous	13.2	6.8

1/ "Principles of Sewage Treatment," Dr. Willem Rudolphs, Rutgers University, 1950.

A toxic material present in industrial wastes must be evaluated individually as a pollutant. Other pollutional characteristics of industrial wastes that should be investigated and reported on an individual basis rather than by comparison with municipal sewage include: dissolved matter, oil and grease, color, taste, odor, acidity or alkalinity, pH, and temperature. Quantities and concentrations vary greatly from one industry to another and even within the same industry.

The procedures employed for treatment of pollutional constituents will remove sizable suspended solids by screening or settling; remove fats, oils and greasy solids by floatation and skimming procedures, aided in some cases by chemical treatment; remove colloidal materials by flocculation with chemical coagulants followed by settling and possibly filtration; neutralize excessive acidity or alkalinity by addition of chemicals; remove or stabilize dissolved solids by chemical precipitation or biological processes or combinations of both; remove color by chemical treatment, with settling or filtration, singly or in combination and reoxygenate the wastes by suitable aeration.

It can be seen from previous discussion that to analyze individual industries as to their particular waste would be a tremendous and complex task involving many detailed field studies for a river basin such as the Ohio. For purposes of this study, it is believed that evaluation of industrial waste loadings in terms of BOD population equivalent will give results consistent with framework type studies that are to provide comparison of pollutional loads between areas and point up future problem areas based on increased pollutional loads as population and industrial activity increases in these areas.

The figure of .25 pounds of ultimate BOD per person per day may be considered as representative of municipal sewage containing a moderate proportion of industrial waste. Highly industrialized communities would have a higher per capita demand, while for small purely residential areas the per capita figure may be lower.

Industrial waste loads were evaluated by type of industry in terms of population equivalents and summarized to quantify waste loads generated for each small area.

Methodology of Waste Load Generated Computation

This report is based on a waste loading of .25 pounds of ultimate first stage BOD per day per population equivalent for domestic and commercial pollutional load. Base or present population equivalents for each economic minor area were summarized from county data compiled from the Public Health Service inventory of Municipal Waste Facilities.

Data on municipal waste loadings given in the inventory include a certain amount of waste from industries that discharge to the municipal system; where population equivalent loadings given exceed the population served, the excess is classed as industrial.

Waste loads from industry for each minor area were summarized from tabular data of each county's industry arrayed by SIC categories and employment. Average population equivalent of waste per employee was assigned to each category and a waste load generated was computed.

Table 12 in each subbasin report summarizes the present untreated domestic, commercial, and industrial waste load generated for the economic areas and the subbasin. The loads shown are either based on available data, both published and unpublished, or are estimated, utilizing the technique described above.

Projected Municipal and Industrial Waste Loads

The population served by sewerage systems given in Table 12 for each minor area is expected to increase at the same rate as that for municipal water supplies. Methodology for arriving at the future population to be served is described in the water supply section.

Industrial waste loads shown for each subbasin are expected to increase at a rate similar to that for industrial water supply. The same index is used as that explained in the industrial water supply section.

Table 13 in each subbasin report summarizes these projected population equivalent loads generated by economic minor area and subbasin to give an order of magnitude of the total untreated pollutional load produced in each for comparison purposes. The waste loads generated shown in Tables 12 and 13 of each subbasin report should not be interpreted as waste loads to the stream. The total loads generated for an area is used as a basis to illustrate the treatment required or flows necessary for quality control after a certain degree of treatment is provided.

Water Quality Problems

Each of the minor areas shown in the subbasin reports was examined for distribution of the waste loads within the area and stream reaches affected. It was considered economically feasible to collect the wastes and reduce the waste load by at least 85 percent by conventional treatment. The remaining 15 percent of the total waste load was assumed to reach the stream and this load as apportioned was compared with the assimilative capacity of the stream. The seven day average low flow with a return period of once in ten years was used as a design flow to determine the assimilative capacity. If the residual waste load after 85 percent treatment exceeded that which would lower the dissolved oxygen in the stream below 4 parts per million at the indicated flow, for a temperature of 25°C, the area was termed a potential problem.

Table 14 in each subarea report summarizes problem areas and the approximate beginning date when problems are expected during low flow periods. Secondary treatment is assumed regardless of treatment at the present time. These tables indicate that there is a need for flow regulation for quality control or other appropriate measures beyond secondary treatment must be taken for pollution control. The general nature of determining waste loadings, area of discharge, degree of treatment and lack of field studies to determine assimilative capacities presented problems in determining flow regulation needs after treatment. However, general order of magnitude of flows required to assimilate wastes after treatment are given in each subbasin report for the major problem areas. These flows are based on the assumptions that treatment will be provided all wastes; that at least 85 percent biochemical oxygen demand is removed; that all settleable solids that will form putrescent demand is removed; that all settleable solids that will form putrescent or otherwise objectionable sludge deposits are removed; that oil, scum, floating materials and substances producing color and odor are removed to such degrees required to prevent unsightly or deleterious conditions; that all substances that are toxic or harmful to human, animal, plant or aquatic life by themselves or in combination are removed; that heated discharges will be sufficiently cooled before discharge to prevent stream impairment for other uses; and that harmful bacteria will be reduced in sufficient number to allow intended stream uses.

Flows discussed in each subbasin report are subject to the following qualifications:

(1) The previous stated treatment of all wastes will be provided.
(2) A water quality objective of 4 mg/l dissolved oxygen is acceptable.
(3) Flow regulation after secondary or equivalent treatment is only one means of water quality control.
(4) Water available from storage for purposes of flow regulation will be of good quality.
(5) Appraisals given are subject to more detailed analysis of specific areas.

Other problems of water quality such as acid mine drainage, brine pollution, heat, taste and odors, and nutrients are discussed, where applicable, in each subbasin report.

III DEFINITION OF TERMS

Primary Sewage Treatment

The first major process or group of processes in a sewage treatment works is usually screening, shredding and sedimentation. This process will remove a high percentage of suspended matter but little colloidal and dissolved matter. It is designed to settle the bulk of organic and inorganic solids that are insoluble. About 30 to 40 percent of the biochemical oxygen demanding materials can be removed but little or none of the more resisting substances.

Intermediate Sewage Treatment

A sewage treatment process or group of processes capable of removing a high percentage of suspended solids and a substantial percentage of colloidal matter but little dissolved matter. This type of treatment is capable of removing up to 75 percent of the biochemical oxygen demand.

Secondary Sewage Treatment

This type of treatment involves the application of a biological process to the primary effluent in which bacterial or biochemical action is intensified to stabilize, oxidize and nitrify the unstable organic matter present. Activated sludge, trickling filtration, contact stabilization and extended aeration are common in secondary treatment.

In the secondary process, suspended and dissolved organic materials that can be attacked by organisms are partially or completely destroyed. Usually 80 to 95 percent of the oxygen demand, as measured by the biochemical oxygen demand test will be satisfied. Although under proper conditions and with sufficient time, all organic materials may be degraded by appropriate organisms, complete degradation does not occur on a practical basis and some residual or refractory materials remain in the effluent.

Advanced Waste Treatment

Selective application of presently uncommon biological treatment and physical-chemical separation processes utilized separately and in combination to remove organic and inorganic contaminants that resist present day conventional treatment processes.

Design Flow

Relating to Water Supply. The one day low streamflow that can be expected to be equalled or exceeded on the average of 29 years out of 30, used as a comparison for water supply needs.

Relating to Quality Control. The seven day average low streamflow that can be expected to be equalled or exceeded in 90 percent of the years, used as a comparison for water quality flow augmentation needs after secondary treatment.

The design flow is not always shown in the tables, however the estimated design flow is discussed in the text.

Water Supply Problem Area

An area where combined dependable surface and ground water resources are or will be insufficient to meet present or projected water supply needs. Problem areas are primarily those of inadequate supply, however where quality problems of supply are known they are listed and discussed.

Water Quality Problem Area

An area where the surface water resource (the design flow) is insufficient to meet the flow required to assimilate present or projected BOD waste injections to a stream assuming that secondary treatment is effected before discharge. Those areas that have problems at present may not be listed as a problem area due to the assumption that secondary treatment is provided.

Satisfactory Stream Conditions

This term relates generally to the amount of dissolved oxygen in the stream caused by the biochemical oxygen demand (BOD) exerted. If the dissolved oxygen concentration is not equal or is not expected to be equal to or above 4.0 mg/l at the point of maximum

dissolved oxygen depletion then stream conditions are unsatisfactory. If dissolved oxygen conditions are equal to or above 4.0 mg/l at the point of maximum sag, satisfactory stream conditions exist.

Population Equivalent (P.E.)

The measure of the strength of a waste converted to an equal number of people required to produce the same biochemical oxygen demand. In terms of ultimate first stage BOD, 0.25 pounds of BOD was considered as one population equivalent.

IV BASIN SUMMARY

DESCRIPTION OF OHIO RIVER BASIN

Location and Boundaries

The Ohio River Basin (exclusive of the area drained by the Tennessee River) has a drainage area of 163,200 square miles comprising parts of 11 States in the East, Central and Northeastern part of the United States (See Figure 1). The basin occupies 1,957 square miles in New York, 15,619 square miles in Pennsylvania, 428 square miles in Maryland, 4,097 square miles in Virginia, 770 square miles in North Carolina, 29,688 square miles in Ohio, 20,513 square miles in West Virginia, 38,038 square miles in Kentucky, 11,354 square miles in Tennessee, 29,317 square miles in Indiana and 11,439 square miles in Illinois. The Ohio River is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, the point customarily designated as river mile zero on Ohio River main stem navigation charts. From this point it flows in a northwesterly direction for about 25 miles then turns westward where it becomes the boundary between Ohio and West Virginia. From here it continues in a southwesterly direction progressively forming the northern boundaries of West Virginia and Kentucky and the southern boundaries of Ohio, Indiana, and Illinois. It joins the Mississippi River at Cairo, Illinois, 981 miles downstream of its origin at Pittsburgh.

The 17 tributary drainage areas listed in Table 3 account for 138,070 square miles or 85 percent of the Ohio River drainage area considered in this report. Approximate mileages from the mouth of the Ohio to the confluence of these tributaries and the main stem are also given.

Physical Features

The Ohio River Basin covers an area including several distinctive physiographic regions. The eastern portion of the basin lies predominantly within the Appalachian Plateau, although portions of the drainage areas of the Monongahela and Kanawha Rivers are in the Blue Ridge and Valley and Ridge provinces (the Appalachian Mountains). The western portion of the basin lies within the Interior

TABLE 3

OHIO RIVER BASIN

Ohio River Tributaries

River Basin	Mileage From Mouth of Ohio River: Northern Tributaries	Southern Tributaries	Drainage Area Square Miles
Allegheny River	981.0		11,700
Monongahela River		981.0	7,400
Beaver River	955.6		3,130
Muskingum River	808.9		8,040
Little Kanawha River		796.4	2,320
Kanawha River		715.3	12,200
Guyandotte River		675.8	1,670
Big Sandy River		663.9	4,280
Scioto River	624.5		6,510
Little Miami River	516.9		1,760
Licking River		510.8	3,670
Great Miami River	489.9		5,400
Kentucky River		435.2	6,970
Salt River		351.1	2,890
Green River		196.8	9,230
Wabash River	133.0		33,100
Cumberland River		60.6	17,920
Main Stem & Smaller Tributaries			24,840
			163,030

low plateau and Central Lowland provinces, except for a relatively small area at the mouth of the Ohio River, where it drains into the lower Mississippi River at the northern tip of the Gulf Coastal Plain. The physiographic setting of the basin and the character of the bedrock formations and unconsolidated glacial and alluvial sediments are described in greater detail in Appendix E prepared by the U. S. Geological Survey (see Appendix E, plates 3, 4, and 5).

Ancient buried river valleys, deeply entrenched in the bedrock and subsequently filled with glacial debris, are widespread subsurface formations of the basin in Indiana, Ohio, northwestern Pennsylvania and New York. The material filling many of these is of a highly permeable composition; their present use and future potential as sources of water supply are among the water assets of the basin. Bedrock throughout the basin is principally of sedimentary origin and varies from dense impermeable siltstones and shales through open textured limestone and sandstone. The degree to which the bedrock is water bearing and forms, or is potentially a significant source of ground water, is with respect to each tributary, locally variable. Specific reference to local condition is made in part 2 on individual basin areas.

The Appalachian coal fields underlie the basin in eastern Ohio, western Pennsylvania, southeastern West Virginia, and eastern Kentucky, while in the western part of the basin, parts of the mid-continental fields are found in western Kentucky and southern Illinois and Indiana. Petroleum deposits are generally found associated with the coal fields as fringe areas along the basin interior edges of the coal deposits and in east-west line across central-western Ohio. Extraction of these materials is an important industrial activity in their respective localities and in respect to coal, reserves are sufficient to sustain the industry over the future period of interest of this study. Extraction and processing of the coal has given rise to acid mine and silt contamination of the local surface drainage while the oil wells have frequently been a source of brine discharge to local surface streams and underground aquifers.

The Ohio River drainage system is almost wholly devoid of natural lakes and swamps. Natural lake areas are found only in the upper headwaters of the Wabash River drainage and these are so limited in extent as to be of only local concern in respect to water supply sources and waste disposal. Notable swamp areas formerly

appeared contiguous with the Wabash lake area region, in the headwaters of the Scioto River and along the lower course of the Wabash and Ohio. However, dikes, dredged ditches and tilling systems have been developed throughout the areas and the lands for the most part have been brought to a well-drained condition. Water conservation reservoirs, ranging in size from farm ponds to municipal, State and Federal developments of tens of thousands of acre-feet capacity, have been developed at many points throughout the basin. Navigation dams creating flow-through impoundments whose pools range in depth from about 6 to 45 feet are located along the main stream and on reaches of nine tributaries. Many of these serve as diversion and temporary storage facilities in the water supplies of communities and industries located adjacent to their pools and all of them modify the natural assimilative capacities of the impounded streams.

Climate

The average annual temperature varies from about 58°F in the Cumberland Basin to about 45°F in the headwaters of the Allegheny and is, in general, uniformly distributed from southwest to northeast between these limits. Average January temperatures range from 25°F to 35°F while those in July are from 70°F to 80°F. Summer maximums of 100°F to 111°F have been recorded throughout the basin while winter temperature extremes are well below freezing and often long enough continued to create ice covering on the surface streams.

The average annual precipitation varies from about 36 inches in the northern part of the basin to about 52 inches in the southern part of the Cumberland watershed, and except for local departures over the Highlands is generally uniformly distributed from north to south. The average precipitation is normally uniformly distributed throughout the year there being only slightly more falling in the spring and summer months than in the fall and winter period. However, wide departures from the average have occurred. During severe drought years as little as 50 percent of the annual average has occurred in various parts of the basin and in some instances, but to a lesser degree of severity, the drought conditions have continued over several consecutive years. Of interest are the effects of such periods on streamflow and the consequent availability of water to areas accustomed in their development to normally humid climatic conditions. As illustration, the years 1930 and 1934 witnessed severe drought throughout the western-central parts of the basin. With an average annual runoff of 10.85 inches the Little Wabash fell to 2.36 inches in 1930 and 2.40 inches in 1934; the White River, average annual runoff 11.38

inches, fell to 3.94 inches in 1930 and 3.49 inches in 1934. These conditions were not limited to Illinois-Indiana portions of the basin but were experienced in a diminishing degree eastward through Ohio and southeastward through Kentucky. Many communities dependent upon run of river water supply sources faced hazardous public health and safety conditions in the curtailment of their supply. Similar, if only slightly, less severe widespread drought conditions occurred throughout the basin during the years of 1936, 1941, and 1954 and more recently for several consecutive years in the early 1960's.

Principal Communities and Industries

The drainage area of the Ohio River considered in this report includes many regions of concentrated population and industrial establishments. There are 21 standard metropolitan statistical areas within the Ohio River Basin representing a total urban population of 7,892,400 people, or 72 percent of the total urban population in the basin. Location of Standard Metropolitan Statistical Areas (S.M.S.A.) are shown in Figure 1.

Except for Nashville, Tennessee, on the Cumberland River,. Lexington, Kentucky on the Kentucky River, and Charleston, West Virginia, on the Kanawha River, these S.M.S.A.'s are spread along the Main Stem Ohio River or in the northern tributary basins.

There are 1,301 communities with 1,000 or more population or an aggregate population of 11,400,000. The following group shows a breakdown of these communities by size groupings:

Population	No. of Communities
2,000-5,000	390
5,000-10,000	212
10,000-50,000	171
50,000-100,000	15
over 100,000	10

Industrially and agriculturally, the area is one of the richer in the Nation. Agricultural land comprises about one-third of the basin. The chief products are corn, hay, oats, livestock, wheat, soybeans, and tobacco. A large share of the national production of steel, coal, oil, natural gas, building limestone, fire clay, asphalt, and fluorspar is credited to the Ohio Basin. Other industries and other products of national importance are automobiles, rubber, electrical machinery, meat packing and tobacco processing.

Pittsburgh, favored in early development by its location at the head of the Ohio River navigation and in the midst of extensive coal deposits, has become an outstanding center of the steel industry. The Allegheny and Monongahela Rivers meet in the city at the tip of "Golden Triangle" to form the Ohio River. It is the center of the bituminous coal region which also contains natural gas, oil, and limestone.

Youngstown, Ohio, is the center of a large pig iron and steel making center and heart of a metropolitan district which includes steel-producing cities of the Mahoning and Shenango valleys (Warren, Niles, Campbell, Struthers and Girard, Ohio and Sharon and Farrell, Pennsylvania).

Abundant mineral resources combined with cheap fuel and power have fostered the development of a large chemical complex at and near Charleston, West Virginia, on the Kanawha River which produces synthetic and natural hydrocarbons, glass and alloys.

Table 4 lists the 21 standard metropolitan statistical areas in the basin, the various counties contained therein, location in the basin and industries that are prominent in the area.

TABLE 4

OHIO RIVER BASIN

STANDARD METROPOLITAN STATISTICAL AREAS

SMSA	County	State	1960 Population Total	1960 Population Urban	Stream Location	Industries
Pittsburgh	Allegheny Beaver Washington Westmoreland	Pennsylvania Pennsylvania Pennsylvania Pennsylvania	2,405,435	1,967,184	Ohio Main Stem head confluence of Allegheny and Lonongahela Rivers	Steel and Iron, coke, aluminum, petroleum products, tin plate, electrical equipment, industrial machinery, clay products, railroad equipment, plate glass, chemicals, hardware, leather, cork products, food products.
Johnstown	Cambria Somerset	Pennsylvania Pennsylvania	280,733	139,383	Allegheny River Basin confluence of Conemaugh River and Stoney Creek	Iron and Steel, bituminous coal, clay products, machinery, machine tools, clothing, packed meat, chemicals, beverages, furniture.
Wheeling	Belmont Marshall Ohio	West Virginia West Virginia West Virginia	190,342	122,404	Ohio Main Stem at Ohio State line	Iron and Steel works; mfg. of tin plate, sheet metal products, nails, chinaware, tiles, glass, paper, textiles, clothing, stogies and other tobacco products, food products, medicines, furniture, plastics; large railroad shops.
Charleston	Kanawha	West Virginia	252,925	168,853	Lower Kanawha River	Huge chemical industries in cities outskirts utilize regions natural resources of salt, brine, bituminous coal, oil, natural gas, clay, sand, iron and timber; oil refineries.
Huntington-Ashland	Boyd Cabell Wayne Lawrence	Kentucky West Virginia West Virginia Ohio	254,780	157,484	Ohio Main Stem	Bituminous coal, oil, natural gas, farm (tobacco, fruit), railroad repair shops, reduction and fabrication of nickel alloys (monel metals), railroad equipment, steel rails, glass, furniture, footwear, ceramics, chemical (dyes), electrical goods, textiles, flour, tobacco products, iron and steel mills, coke works, oil and gas refineries, heat resistant equipment, auto parts.

TABLE 4 (cont'd)

OHIO RIVER BASIN

STANDARD METROPOLITAN STATISTICAL AREAS

SMSA	County	State	1960 Population Total	Urban	Stream Location	Industries
Canton	Stark	Ohio	340,345	244,012	Upper Tuscarawas River tributary to Muskingum River	Iron and Steel Processing, roller bearings, oil refinery, diesel and gas engines, electric cleaners, rubber products, brick meat products, clothing, chemicals, fire clay and coal mining.
Steubenville-Weirton	Brooke Hancock Jefferson	West Virginia West Virginia Ohio	167,756	98,694	Ohio Main Stem 30 miles west of Pittsburgh	Steel center, coal and clay producing area, tin plate, paper products, pottery, electrical tools, chemicals, cement products.
Columbus	Franklin	Ohio	682,962	629,387	Scioto River at mouth of Olentangy River	Railroad hub, meat packing, printing and publishing paper mills, foundry products, aircraft and auto parts, electrical and heating equipment, glass, footwear, clothing. Trade center for rich farm area.
Youngstown-Warren	Mahoning Trumbull	Ohio Ohio	509,006	391,354	Mahoning River tributary to Beaver River, 55 miles north of Pittsburgh	Pig Iron and steel making center, steel milling, fabricated steel, bronze products, electrical equipment, motor vehicles, rubber tires, furniture, coke, chemicals, cement, auto parts, commercial gases.
Springfield	Clark	Ohio	131,440	94,264	Mad River tributary to Miami River	Agricultural and construction machinery, motor vehicles, foundry and machine shops, electrical goods, engines and turbines.
Dayton	Montgomery Miami Green	Ohio Ohio Ohio	694,623	597,344	Great Miami River at confluence of Mad and Stillwater	Cash registers, refrigerators, air conditioning equipment, precision tools, electrical equipment, aircraft and auto parts.
Hamilton-Middletown	Butler	Ohio	199,076	152,036	Great Miami River - 18 miles north of Cincinnati	Paper products, paper mill machinery, steel and iron products, furnaces, safes, diesel engines, steel rolling mills, tobacco products, and woolens.

TABLE 4 (cont'd)

OHIO RIVER BASIN

STANDARD METROPOLITAN STATISTICAL AREAS

SMSA	County	State	1960 Population Total	Urban	Stream Location	Industries
Cincinnati	Hamilton Campbell Kenton	Ohio Kentucky Kentucky	1,071,624	990,746	Ohio Main Stem Mid Ohio River	Breweries and distilleries, soap, packed meat, stockyards, machine tools, steel products, chemicals, plastics, watches, clothing, shoes, paper, ink, vehicle bodies, machinery foundries, wire goods, electrical equipment, tile, brick, oil refineries.
Louisville	Jefferson Floyd Clark	Kentucky Indiana Indiana	725,139	621,259	Ohio Main Stem 90 miles southwest of Cincinnati	Tobacco market and processing center, large distilleries, meat packing, foundries, machine shops, flour mills, food processing, farm equipment, leather goods, electrical goods, furniture, paint, synthetic rubber, chemicals, cement, heating and refrigerating equipment, railroad car works, animal oils, soap, clothing.
Lexington	Fayette	Kentucky	131,906	111,940	Kentucky River Basin 75 miles southeast of Louisville	U. S. center for raising of thoroughbred horses, important market for looseleaf burley tobacco, livestock (horses, cattle, lambs), tobacco processing, limestone products, cutting tools, sheet metal products, furniture, electrical equipment, auto parts, flour milling.
Terre Haute	Vigo	Indiana	108,458	81,415	Wabash River Main Stem	Commercial, industrial and banking center of coal mining and agricultural area. Mfg. of brick, tiles, paint, coke by products, steel products, paper and pasteboard containers, clothing, pharmaceuticals and food products.
Muncie	Delaware	Indiana	110,938	77,504	West Fork White River 50 miles northeast of Indianapolis	Railroad, industrial, and trade center in agricultural area. Mfg. of glass products, automobile parts, electrical equipment, steel and wire products, cutlery, silver plate ware, home canning equipment, furniture, bedding; dairying and meat packing.

TABLE 4 (cont'd)

OHIO RIVER BASIN

STANDARD METROPOLITAN STATISTICAL AREAS

SMSA	County	State	1960 Population Total	1960 Population Urban	Stream Location	Industries
Indianapolis	Marion	Indiana	697,567	635,933	West Fork White River	Large stockyard, railroad shops; flour and hosiery mills, printing and publishing firms; mfg. of pharmaceuticals, automobile bodies and parts, machinery, metal products, construction materials, paint, food products, clothing.
Champaign-Urbana	Champaign	Illinois	132,436	100,130	Embarrass River tributary to Wabash	Commercial and industrial center in agricultural area (corn, wheat, soybeans, alfalfa, oats, livestock, poultry). Mfg. of dairy and soybean products, tiles, gloves, machinery, chemicals, bleaches, polishes, cleansers, concrete and metal products, disinfectant, scientific instruments; oil refining.
Nashville	Davidson	Tennessee	339,743	350,599	Cumberland River	Commercial, transportation, industrial and educational center of middle Tennessee. Processing point for limestone soil, livestock and agricultural products. Mfg. of cellophane, corfam, tobacco products, clothing, fertilizers and farm implements; flour and feed milling; oil refining; and publishing.
Evansville	Vanderburgh Henderson	Indiana Kentucky	199,313	160,552	Ohio Main Stem	Agricultural and coal mining region. Mfg. of furniture, automobiles, refrigerators, meat packing, farm and excavating equipment, stoves, glassware, drugs, chemicals and textiles.

THE ECONOMY

General Description of Basin Economy

The Ohio River Basin encompasses areas of great resource diversity and of considerable difference in the degree of economic development. The northeastern part of the basin, which includes Pittsburgh, Pennsylvania, Youngstown, Ohio, and Wheeling, West Virginia, is one with a very high degree of urbanization with heavy emphasis on manufacturing, particularly the production of durable goods and steel. The southern and southeastern portions of the basin are in the central and eastern upland region, which is characterized by a high proportion of hilly land, large families, but lower than average population growth because of high out-migration of people, relatively great importance of mining, large number of small-scale or part-time farms, and a large number of small and medium-sized cities having a chronically high unemployment problem.

The remainder of the basin, i.e., Western Ohio, most of Indiana, and Eastern Illinois, encompasses a large part of the Nation's breadbasket and also contains important machinery and fabricated metal products manufacturing complexes. The growth of major metropolitan concentrations in this region has accompanied the westward expansion of the U. S. manufacturing belt across the northern half of Ohio, Indiana, and Illinois.

Population

In 1960, the basin contained over 19 million people or about 11 percent of the continental United States. This share has gradually been decreasing since the beginning of the century when the basin accounted for 14 percent of the total. It is projected to decline even further, though at a slower rate, so that at the end of the 50-year projected period, the basin may be expected to account for only eight percent of the Nation's population or about 31.6 million people. The projected difference in rates of population growth between the basin and the Nation primarily stems from the assumption of a continued outward movement of people to other areas in the Nation in response to interregional differentials in economic opportunity.

The historical lag of the region behind the Nation was accentuated during the 1940-1960 period when out-migration from the basin reached its peak. During 1950, when the national rate of natural increase reached new highs, the U. S. population grew at twice the rate of the basin.

Urbanization

Historically, the trend has been for increased urbanization. This is so primarily because of increased industrialization and improved technology in agriculture and mining. An indication of the rural-urban shift is that in 1880, the urban percentage was only about 30 percent while in 1960, it was about 70 percent and is projected to be over 80 percent by 2010.

Personal Income

Projections of personal income were derived from the econometric model which was used to project output by industry sectors. Total personal income in the basin in 1960 was about $38 billion with a per capita personal income of about two thousand dollars. By 2010, the basin is expected to reach a total personal income of $212 billion and a per capita personal income of about seven thousand dollars. This is a 237 percent increase in per capita income which compares to an increase of 245 percent for the Nation during the same period.

Labor Force and Employment

The labor force of the basin, which in 1960 accounted for about 36 percent of the total population, is projected to grow somewhat more rapidly than the population because it is expected that as the basin becomes more urbanized and as the birth rate declines, there will be an increase in labor force participation, particularly among women.

The industry employment pattern of the basin bears a marked structural resemblance to that of the Nation, particularly when the comparison is made at a level of industry aggregation such as agriculture, manufacturing, trade, etc., which masks some of the differences that would appear in a detailed industry composition comparison. In the basin as in the U. S., manufacturing accounted for a growing share of total employment between 1930 and 1960. However, in the basin, manufacturing continues to be more important as a source of employment (about 31 percent in 1960) than in the country as a whole (about 27 percent).

It is in the mining sector that the most important differences between national and regional employment shares are to be found. The basin, which produces about three-quarters of the country's bituminous coal, had about three percent of its working population engaged in mining in 1960, while the national share was only one percent. It is noteworthy, however, that in mining, unlike in manufacturing, the employment share has undergone a drastic decline, especially since 1950. In the Nation as a whole, that share declined by almost 40 percent, while in the basin it declined by more than 55 percent during the 1950-1960 decade. This difference resulted from the facts that coal mining makes up a much greater proportion of total mining in the basin than it does in the Nation, and application of technological advancements in coal mining have been greater than in other types of mining.

Agricultural employment also decreased as a share of total employment. In 1930, agriculture accounted for more than 20 percent of total employment, whereas in 1960 it accounted for less than seven percent regionally as well as nationally.

The historical decrease in the contribution of agriculture and mining to total employment in the basin is partially offset by the growing proportion of jobs in the trades, services, and the government sector. This trend is evident at both national and regional levels, but in 1960 the basin still trailed the United States in these categories of employment.

Manufacturing Output

The gross output of manufacturing industries expressed in constant dollars is projected to double between 1960 and 1980 and then grow by another 143 percent between 1980 and 2010. Electrical machinery, transportation equipment, and chemicals top the list of the basin's growth industries.

WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present Municipal and Industrial Water Supply

In 1963 there were 1,908 municipal water supply facilities in the Ohio River Basin furnishing water to 13,900,000 persons. This number of facilities represents 10 percent of the municipal water supply facilities and 9 percent of the population served of the United States. This population served represents about 72 percent of the total population and 1.2 times the population classed as urban in the Ohio River Basin. Five years earlier (1958) there were one million less people served from central facilities. This population served represented 58 percent of the total Ohio River Basin population and slightly more than the urban population of the basin.

During this same five year period (1958-1963) the total population of the basin increased 1.03 times, the urban 1.08 times and the population served from central water facilities 1.28 times. Thus we see that the population served has increased at a rate 1.24 times the total population rate and 1.18 times the urban rate for the five year period. The number of facilities in operation has remained about the same for this period.

Sixty-five percent of the above facilities are publicly owned and account for 71.6 percent of the population served. The majority of the facilities utilize ground water sources (66.9 percent) but account for only 31.2 percent of the population served; 83.6 percent of the facilities have some type of treatment and account for 97.7 percent of the population served.

Figures 4 and 4a illustrate the status and breakdown of municipal water facilities by number of plants and population served as to sources and type of treatment.

The total water use for municipal and industrial purposes amounted to 10,685 million gallon per day (mgd) in the Ohio River Basin. The amount excludes that withdrawn for cooling in thermal electrical power generation. Approximately 83 percent (or 8,900 mgd) was used for industrial purposes, of which about 98 percent is returned to the stream for further use. Approximately 90 percent of that used for domestic and commercial purposes are returned as waste flows.

The present total municipal and industrial water use for each subbasin and main stem section is shown numerically in the center of Figure 5.

The largest combined use is in the Monongahela River Basin and accounts for 45.5 percent of the Ohio River Basin water use. The Kanawha River Basin accounts for 14.1 percent, the Beaver Basin 9.9 percent, and the Allegheny and Wabash account for 4.7 percent and 7.1 percent respectively.

The Ohio River Main Stem accounts for only 10.9 percent of the total municipal and industrial water use in the basin excluding a very large use by thermal electric plants along the main stem.

Projected Municipal and Industrial Water Supply

Figure 5 compares the projected municipal and industrial water use to the basin as a whole and projected use within the subbasin as multiples of present use. Present water use within the basin is shown numerically in the center of the graph. The right side shows the comparison of each basin to the total water use within the entire Ohio River Basin. To the left of the graph the absolute growth projected for each subbasin is compared with one another and the total basin. Also shown on the left is a compounded growth rate to compare growth rates projected for each subbasin.

The general westward movement of population and industry in the basin is apparent in the water use. Although the Monongahela River Basin presently accounts for 45 percent of the M&I water use in the basin, it is projected to be reduced to 38.6 percent of the Ohio River Basin water use by 2020, even though its absolute water use is expected to double by 2020 as seen on the left of Figure 5. Similarly, the Beaver River and the upper Main Stem Ohio follow this pattern.

The western or lower subbasins of the Ohio all show increased water use by 2020 as a percent of the basin. Absolute increases average about four to five times the present usage. Generally, where the present base is smaller the percentage of increase in absolute water use is greater.

Water Supply Problems

Figure 5 summarizes the present and projected water use by subbasin indicating the order of magnitude of use. Although useful

to compare one subbasin to another, and trends of usage for a larger area, water use for an entire subbasin does not present the complete picture as to water shortages within a subbasin. The distribution of this use and its availability for reuse may considerably reduce the amount of water indicated to meet the needs. Also the ground water availability and runoff will vary in different parts of the subbasin.

The subbasin reports indicate the spread of water use throughout each subbasin and those stream reach areas that will be short of sources of supply for municipal and industrial purposes based on the current design capability of surface and ground water systems.

Table 5 summarizes the cumulative number of problem areas for each subbasin by projected time periods thereby indicating the order of priority for more detailed individual basin studies of water supply needs.

TABLE 5

OHIO RIVER BASIN

Summary of Water Supply Problem Areas

No.	Subbasin	Cumulative Number of Problem Areas			
		Present	1980	2000	2020
1	Allegheny	1	7	12	13
2	Monongahela	2	4	4	4
3	Beaver	0	4	4	4
4	Muskingum	4	18	23	23
5	Kanawha	3	5	5	5
	Little Kanawha	1	1	1	1
6	Guyandotte	0	0	0	0
	Big Sandy	0	0	0	0
	Little Sandy	0	0	0	0
7	Scioto	1	8	14	15
8	Great Miami	0	15	25	25
	Little Miami	3	11	12	12
9	Licking	3	5	5	5
	Kentucky	4	5	5	5
	Salt	0	1	2	2
10	Green	3	4	4	4
11	Wabash	10	23	37	39
12	Cumberland	1	5	10	15
13	Main Stem Upper 1/	0	17	22	22
	Main Stem Huntington 2/	0	2	3	3
	Main Stem Cincinnati 3/	2	7	8	8
	Main Stem Louisville 4/	4	5	5	5
	Main Stem Evansville 5/	2	7	7	7

1/ Includes Hocking River, Chartiers Creek, Little Beaver and Robinson Run.
2/ Includes Raccoon Creek.
3/ Includes Mill Creek, Laughery Creek and Tanners Creek.
4/ Includes Pleasant Run, Big Indian Creek and Big Blue River.
5/ Includes Saline River.

SOURCES OF MUNICIPAL WATER SUPPLIES IN OHIO RIVER BASIN-1963

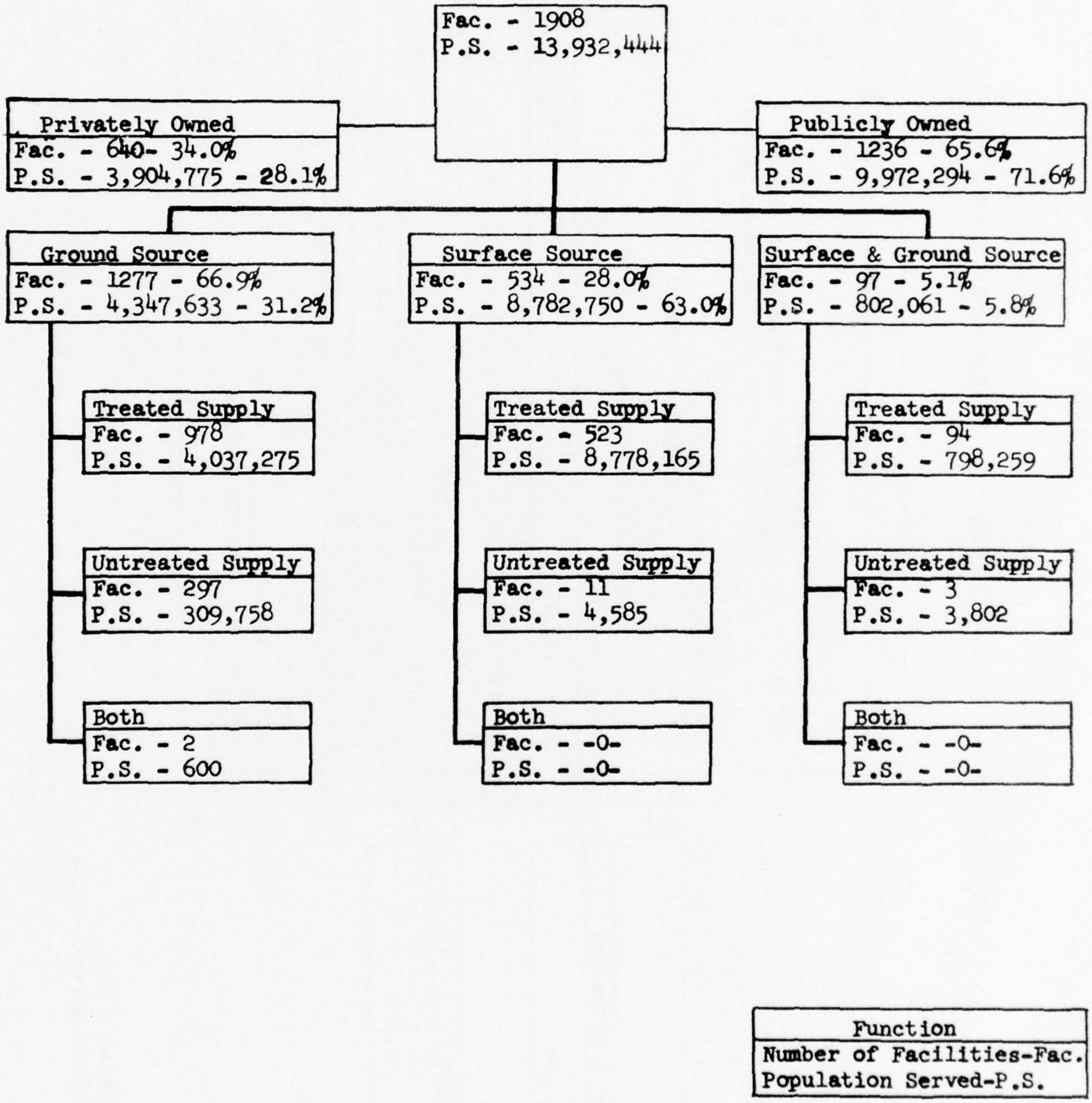


Figure 4

TREATMENT OF MUNICIPAL WATER SUPPLIES IN OHIO RIVER BASIN-1963

Fac. - 1908
P.S. - 13,933,444

Treated
Fac. - 1595 - 83.8%
P.S. - 13,613,699 - 97.7%

Treated & Untreated
Fac. - 2
P.S. - 600

Untreated
Fac. - 311 - 16.3%
P.S. - 318,145 - 2.3%

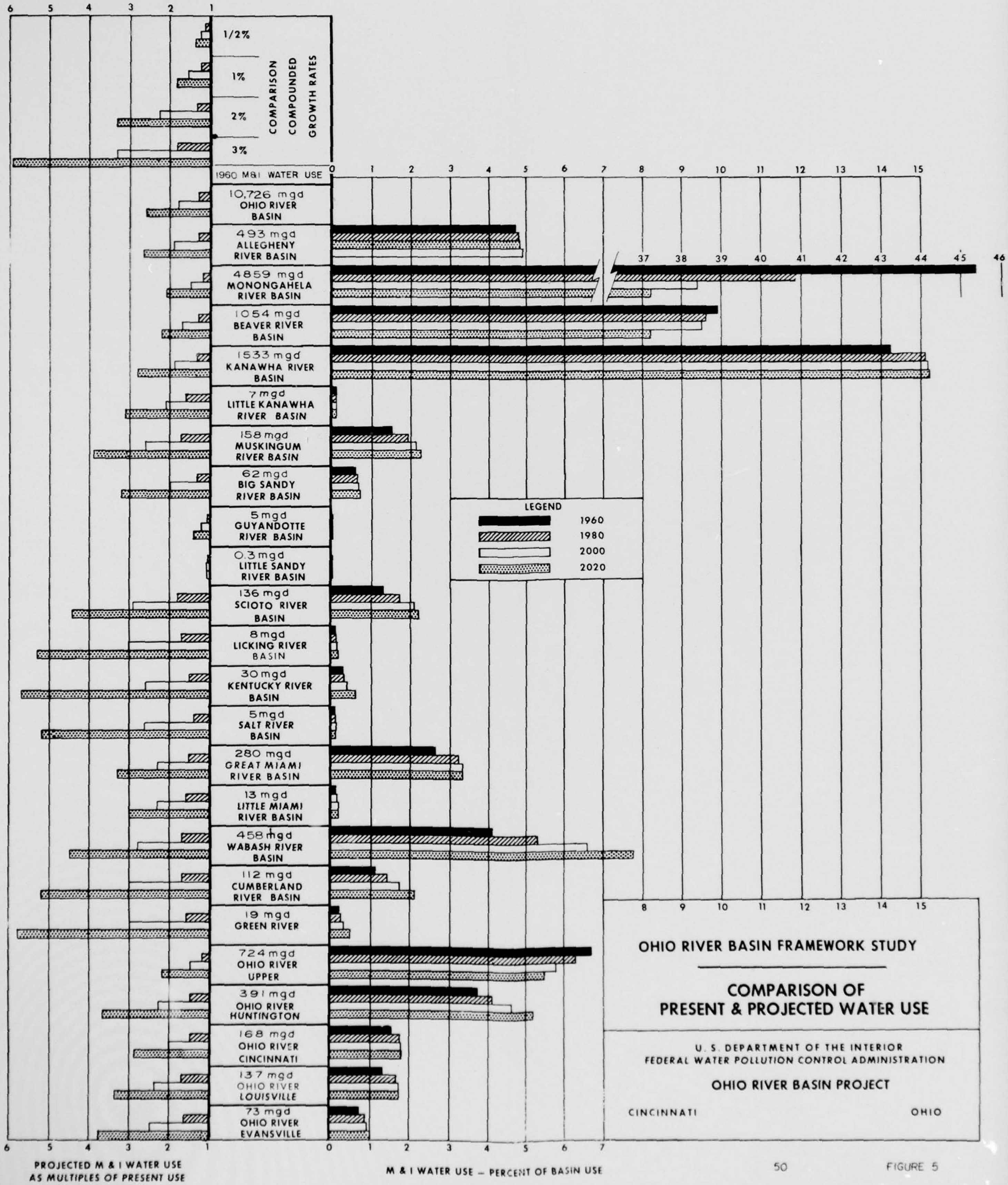
TYPE TREATMENT	% of Plants	% Pop.Served
Purification Only	31.1	56.2
Purification and Softening	3.6	15.3
Purification, Iron removal and Manganese removal	.8	.8
Purification, Softening, Iron and Manganese removal	.5	.4
Softening only	6.8	5.4
Iron and Manganese removal	12.1	5.8
Softening, Iron and Manganese removal	4.4	2.0
Disinfection only	29.4	7.8
Disinfection and Miscellaneous	9.5	5.0
Miscellaneous	1.7	1.2

UNIT PROCESS	% of Plants	% Pop.Served
Gravity Rapid - Sand Filters	38.4	70.1
Aeration	27.1	26.1
Taste and Odor Control	16.2	55.8
Corrosion Control	23.3	41.6

LABORATORY CONTROL

ANALYSIS RUN	% of Plants
Chemical	38.6
Bacteriological	.8
Chemical and Bacteriological	13.2
None	31.4

Facilities - Fac.
Population Served - P.S.



OHIO RIVER BASIN FRAMEWORK STUDY

COMPARISON OF PRESENT & PROJECTED WATER USE

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

OHIO RIVER BASIN PROJECT

CINCINNATI OHIO

FIGURE 5

WATER QUALITY CONTROL

Present Municipal and Industrial Waste

In 1962 there were 1,293 municipal sewerage facilities in the Ohio River Basin serving a population of 11,357,121 people in 1,399 communities. The prestated numbers represent 11.1 percent of the municipal sewerage facilities and 9.6 percent of the nation's total population connected to sewers. It represents 58 percent of the Ohio River Basin total population and is slightly more than the population classed as urban in the basin. Sixty-two percent of sewerage systems have some form of treatment before discharge and serve 88 percent of the population served by sewers and 50 percent of the total basin population. Of the 803 sewerage facilities that have treatment, 518 have secondary, 26 have intermediate, and 258 have primary treatment. A graphic summary of municipal sewerage facilities and treatment is illustrated in Figures 4 and 4a.

There are noticeable increases in the percent of connected population discharging treated and raw sewage to the Ohio River Basin and its tributaries in the five year period, 1958-1962. This increase amounted to 28.6 percent of the population served and has climbed from 19.3 percentage points below the national average in 1958 to equal the national average of 87.6 percent in 1962.

As of July 1, 1965 the Ohio River Valley Water Sanitation Commission (ORSANCO) reports a sewered population of 11,400,000 with 93 percent of this population served by treatment. Degree of treatment provided is 25 percent primary, 25 percent intermediate, and 48 percent secondary. The ORSANCO district embraces portions of eight States; Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia and West Virginia and covers 95 percent of the land area and 92 percent of the total population covered in the Type 1 report.

Within the ORSANCO district there are 1,723 industrial establishments whose effluents are discharged directly to streams. Of these, 90 percent have installed facilities that are reported to comply with minimum control requirements established by ORSANCO.

The industries discharging the majority of organic waste load to the streams include food processing plants, paper and allied products plants, and chemical plants. Inorganic wastes include acid

from steel plants, toxic metal wastes, phenols and other taste and odor producing substances from coke and chemical plants, brines, sulphates, color producing substances, and silt from coal washing operations.

Phenolic compounds, while of minor importance from the biochemical oxygen demand standpoint, give rise to offensive tastes and odors in public water supplies. Their removal within the water treatment plant is difficult and costly.

The raw municipal and industrial waste loads generated in the Ohio River Basin approximate 23 million in population equivalents, of which about 63 percent is presently removed by waste treatment before entering the stream. The basins generating the largest quantities of waste in relation to the total basin are the Wabash, Upper Main Stem Ohio, Kanawha, Ohio River Main Stem-Cincinnati, Great Miami and Scioto Rivers in order of magnitude. These six basin areas account for 54 percent of the total organic load generated in the basin. Figure 7 compares the present raw waste loads generated in each tributary basin compared to the total Ohio River Basin.

Projected Municipal and Industrial Wastes

Figure 7 illustrates how each tributary basin raw waste loads are projected to increase in relation to the total Ohio River Basin. Absolute projected increases over the present base are shown on the left on the figure for the time periods 1980, 2000, and 2020 and are compared to different growth rates for the same time periods at the top of the page.

The Wabash River Basin has the largest amount of the organic waste load generated of the basin tributaries. The metropolitan Indianapolis area accounts for about one-third of the domestic and commercial and almost one-half of the industrial organic load generated of the entire Wabash Basin. As seen in Figure 7 there is projected a fourfold increase in the amount of wastes to be dealt with in the basin. The upper main stem area has the Pittsburgh complex as the major contributor of wastes, the Kanawha River has the Charleston complex, the Great Miami River has the Hamilton, Dayton, Middletown area and the Scioto has Columbus. All of these areas are metropolitan areas which contribute the major portion of the municipal and industrial wastes of the individual basins.

2) Alteration of land use, manufacturing processes, and public practices to reclaim or reduce amount of waste that is waterborne.

3) Regulation of streamflow or other modifications of the capacity of the waterway to receive waste and still preserve quality (includes importation of water from other basins).

4) Regulate waste discharges to vary with streamflow and take advantage of favorable hydrologic conditions either as observed or as forecast. This would include waste diversion to streams with higher flow or at least higher assimilative capacity.

The Type 1 study points up those areas where organic waste loads are now causing problems or will cause them in the future. A combination of the above methods was chosen to evaluate these areas; that of secondary treatment and the assumption that streamflows can be regulated to meet the needs after such treatment.

In some of these areas it is doubtful that hydrologic conditions will permit enough storage for the purpose of regulation of streamflow for water quality control after secondary treatment and as such appears to be only a partial or interim solution to the problem. Examples of the larger problem areas that fall in this category are as follows.

Indianapolis, Indiana on the White River where summer low flows of 105 cfs are not capable of assimilating present residual organic waste loads without degradation even though a high degree of treatment is presently practiced. It is estimated that flows in the order of 2000 cfs would be required to assimilate waste loads after secondary treatment by the year 2020. The average annual flow at the point of waste injection at Indianapolis is on the order of 1700 cfs, and therefore is insufficient to handle these year 2020 waste loads even with complete streamflow regulation.

The Charleston complex on the Kanawha River contributes the major municipal and industrial organic waste loads to this basin. The chemical and allied product industries are most prevalent and the organic portion of their waste load is only one of a number of pollution aspects attributed to this type of industrial waste. Other major problems are toxicity, color, and taste/odor properties. With the provision of secondary treatment of municipal and equivalent industrial wastes removal, summer flows as high as 7,800 cfs are estimated to be required by the year 2000. This exceeds the present modified dependable flow below Charleston by 5,870 cfs and is about

Distribution of raw wastes generated for each tributary area is shown in Tables 12 and 13, of the individual basin reports. Secondary treatment was assumed in all cases. The residual wastes to the stream were compared to the assimilative capacity at design low flow. Where the assimilative capacity was exceeded the stream reach was noted as a problem area.

Organic Water Quality Control Problem Areas

Table 6 summarizes the number of organic water quality problem areas in each subbasin and their beginning dates in terms of time periods in the future, unless solutions to the problems have been found in the interim. At the present time there are 192 organic problem areas as defined in the Type 1 study. After secondary treatment, the discharge of these wastes in these areas will create low dissolved oxygen conditions in the stream during periods of low flow. If action is not taken to correct such situations, the number of such problem areas are expected to increase to 171 by 2020. As seen in the table these problems are already upon us in many of the basins. These areas are defined in the individual basin reports with the approximate flows required in the stream to assimilate projected wastes after secondary treatment.

In some basins, the effects of organic waste loads are intensified or masked by other types of pollution. In the Mahoning River of the Beaver River Basin, organic waste problems are intensified by the discharges of heated water that accelerate the biologic activity while at the same time decreasing the oxygen saturation value of the water.

Portions of the Allegheny and Monongahela Rivers are highly acid due to mine drainage. In these areas, the organic waste effects are masked as the biological activity is greatly reduced or inhibited.

Corrective Measures-Organic Water Quality Problem Areas

Basically there are four methods of controlling water pollution. Any one of these methods or a combination of them can be applied in a particular situation to produce the desired results. The four methods are:

1) Collection and treatment of municipal and industrial waste water to remove or degrade polluting substances before waste is discharged to waterway (includes advanced waste treatment methods).

75 percent of the average annual flow. Providing storage for quality control in the basin is complicated in that the Kanawha River is (1) a navigable stream, and (2) the navigation pools and some upstream reaches are developed for hydroelectric power. The navigation requirement reduces the assimilative capacity of the stream, and energy is converted to electric power rather than used to restore lost oxygen by turbulence. In addition, peaking power flows compounds the damage to natural conditions.

The Great Miami River below Dayton with a design summer flow of 175 cfs is not capable of assimilating present residual organic waste loads although removal is in the order of 90 percent. Approximately 1,400 cfs will be required by 2020 below the Dayton sewage treatment plant to maintain satisfactory stream conditions. To maintain this flow would require 68 percent of the average annual flow in the stream at Dayton, a condition that would appear to be infeasible under the present day concept of multipurpose reservoirs. Topographic and physiographic conditions and land utilization in the basin would further preclude providing enough storage.

The major water quality control problem in the Scioto River is below Columbus, Ohio. Columbus presently operates secondary treatment facilities and obtains BOD reductions of 80-90 percent. Flows in the order of 780 cfs will be required by 2020 to assimilate residual waste loads. This flow would require close to 60 percent regulation of the basin average annual flow above Columbus. Further detailed studies would be required to make a firm decision as to whether flows of this order could be maintained. However, present conditions would indicate it is not practical to provide this storage under present multipurpose concepts, especially considering demands for municipal and industrial water supply and flood control.

Canton, Ohio is located on Nimishillen Creek, tributary to the Tuscarawas River in the Muskingum Basin. It is a large scale example of a typical problem faced by many smaller communities located in headwater areas. Streamflows are very low or intermittent and it appears that possibilities of storage of water for quality control are limited in such areas. Design flow in Nimishillen Creek is about 23 cfs but flows in the order of 320 cfs would be required by 2020 to assimilate wastes after secondary treatment. Average annual flow in the stream is about one-half this amount and therefore rules out the possibility of enough storage for flow regulation for quality control unless transbasin diversion is considered.

There are many smaller communities in the basin located in headwater areas such as Canton. Usually there is sufficient ground water or surface impoundment available for water supply, but not enough streamflow remaining to assimilate residual wastes.

Detailed studies of individual wastes, hydrology and pertinent factors will be required in the areas mentioned to determine the most feasible solution to the problem. Streamflow regulation is a partial and interim solution. Diversion to other basins is not practical in these areas because of the large quantities of wastes and detriment to the basins where the wastes are most likely to be diverted. Holding ponds do not seem to be feasible in these areas because of high degree of urbanization and cost of land required for storage of wastes would be expensive even if esthetic considerations are set aside.

In areas such as Cincinnati and Pittsburgh on the main stem, flow regulation after secondary treatment is feasible to provide the required assimilative capacity during periods of low flow. Specially constructed outfalls may be necessary to obtain proper dispersion and mixing of the residual wastes. In these and many other areas of the basin there are present organic water quality problems during low flow periods because less than secondary treatment is presently provided.

Separation of municipal sewage and storm drain systems in future construction would reduce the amounts of raw sewage discharged to the stream. Presently about half the population served by sewers in the basin are discharging waste to combined systems. These systems are subject to direct overflow of raw sewage during wet periods. Engineering practice has been to provide for the interception and treatment of a flow equal to two or three times the average dry-weather flow. All flows in excess of this are by-passed to the watercourse, generally at numerous points in the system. The frequency of these overflows is as much as five or six times a month during the summer. Although it can be shown that about 3 percent of the sewage that originates in the system is lost through the overflows, as much as 20 to 30 percent of the organic matter may be discharged with it. This condition is the result of the deposition of the solid matter in the pipes during the dry weather and its subsequent scouring during storm runoff periods. This imposes a large pollution load on the watercourse.

The solution to storm water overflow does not pose any great technological problem, but there appears to be no solutions that will not require large expenditures. The basic problem relates to the handling of large volumes of runoff, which occur in very short periods of time. Among the solutions that can be considered are:

1) The complete separation of sanitary and storm-sewers.

2) Holding tanks or ponds to receive the excess runoff and then release it slowly to the treatment plants or watercourse.
3) Large treatment plants that could provide some measure of treatment to the mixture of sewage and storm water before release to the watercourse.

The practicability of the treatment of excess combined sewage is a matter of individual investigation of the problem area.

Some areas in the basin are approaching the point in the near future where flow regulation after secondary treatment will not meet the water quality control needs. In these areas advanced waste treatment methods are being thought of as alternate solutions to the problem.

Many new physical-chemical separation processes are emerging as candidates for major roles in the waste treatment technology of the future. As these processes are developed and brought into use higher effluent quality will be achieved. As this quality increases, the effluent itself will become of more and more value. At some point, depending on the total water resource picture at the location involved, the effluent may become too good to discharge back to the stream and deliberate recycle for water supply will be developed.

At the present time, practical and economical water renovation techniques do not exist beyond the pilot plant scale. They must be further developed to meet the needs of the future if chemical, biological pollutants are to be kept from the waterway and if taste and odor-bearing materials and potentially toxic substances are to be eliminated.

In contrast to sedimentation techniques and biological oxidation which represent the basic concepts of conventional waste treatment processes, advanced waste treatment considers the physical-chemical separation processes that have the ability to remove dissolved salts and complex synthetic organic wastes unaffected by standard treatment.

Various advanced waste treatment processes studied to date include: adsorption, electrodialysis, foaming, distillation, solvent extraction, emulsion separation, freezing, hydration, chemical oxidation, ion exchange, electrochemical degradation and reverse osmosis.

Four of the above mentioned processes have good prospects of development for large scale operation.

Process	Cost per 1000 gal.	Scale
Adsorption by activated carbon	Less than 10 cents	10 mgd
Foam Separation	3-5 cents	10 mgd
Electrodialysis	15-20 cents	10 mgd
Distillation	Less than 1 dollar*	10 mgd

Methods of final disposition of the concentrated wastes from these processes must be found in order to prevent repollution. Methods considered to date include: subsurface disposal into permeable strata or cavities; wet oxidation, incineration, conveyance to selected dump sites (e.g., the sea) by barge, truck, or pipeline; and recovery of waste materials to make useful products.

The technological adequacy of a separation process or an ultimate disposal process becomes the overriding criterion for determining the practicability of any given approach to advanced waste treatment. Of major importance, however, is the matter of economics; a number of processes are technically capable of achieving the desired end results but at an unreasonably high cost. Hence, the final measure of success of a particular process in any one area will be the cost, not only of the individual separation techniques, but of the complete treatment and disposal operation.

The typical municipal water use cycle includes: (1) source development and transmission, (2) water treatment, (3) water distribution, (4) waste collection, and (5) waste treatment and disposal. Since advanced waste treatment could accomplish (1), (2) and (5), the sum of these costs in today's technology can reasonably be used as a base line to estimate the competitive position in considering these treatment methods in a particular area. The total cost of these functions amounts to about 23 cents per 1,000 gallons on a national average and 30 cents per 1,000 gallons in prevailing high-cost areas of the country.

*Cost could be less than one-half this amount when process is coupled with blending.

A technology using new and more complex processes is not expected to compete on an equal basis cost-wise with present treatment technology. The "law of diminishing returns" will dictate in areas that are now stretching the limits of today's techniques and more complete and selective treatment will be necessary.

Acid Mine Drainage Problems

The quantitative pollutional effects of acid drainage has not been evaluated in detail in the Type 1 study. Sources of acid mine drainage pollution are numerous, particularly abandoned coal mines. The most comprehensive summary of acid mine drainage pollution available is contained in the Ohio River Pollution Control Survey (published as House Document 266, 78th Congress, 1st Session). This report reflects conditions as of 1940. The total acid load before sealing accomplished at that time was estimated in terms of its calcium carbonate equivalent as follows: active mines 1,105,000 tons per year; marginal mines 175,000 tons per year; abandoned mines 1,141,000 tons per year; the total being 2,421,000 tons per year. After sealing, the residual acid load from all mines was estimated at 1,801,000 tons per year.

In some areas a great many of the previously sealed mines have been reopened for production of coal and new mines have been developed. The effectiveness of the sealing operation has been reduced due to inadequate maintenance of the seals and in the cases of drift mines failure of the seals to exclude oxygen.

The magnitude of the acid mine drainage problem can be recognized when it is realized that approximately 75 percent of the Nation's bituminous coal supply comes from the Ohio River Basin, only about 10 percent of the coal reserves have been mined and approximately 50 to 75 percent of the acid load comes from abandoned mines.

Of the portions of the 11 states comprising the basin for the Type 1 study, nine are considered to have significant acid mine drainage pollution problems. The States of Pennsylvania and West Virginia contain over two-thirds of the miles of streams and 90 percent of the acres of impounded water affected by acid mine drainage in the Ohio Basin.

More than half of the acid load originates in the Monongahela and Allegheny subbasins. In the Allegheny Basin, the Kiskiminetas River drainage is one of the most intensely acid polluted areas known. This watershed contains over 500 miles of acid polluted streams and receives about 80 percent of the acid loading of the Allegheny River Basin.

The Monongahela River Basin contains over 1600 miles of streams affected by mine drainage and receives about 35 percent of the total acid per year generated in the entire Ohio River Basin. Particularly concentrated acid-producing areas are the number of small tributaries to the main stem between Fairmont, West Virginia, and Pittsburgh, Pennsylvania. These areas contribute about 70 percent of the residual mineral acidity in the Monongahela River.

Further downstream, the Hocking River and Raccoon Creek in Ohio, and other streams contribute significant acid loadings to the main stem Ohio River. Raccoon Creek, for example, was found to be discharging 16 tons per day of equivalent sulphuric acid to the Ohio River. Other concentrated acid pollution areas exist in the coal mining regions of the Muskingum, Kanawha, Guyandotte, Big Sandy, and Upper Cumberland River Basins.

Mining in the eastern interior coal field of the lower basin has caused pollution problems similar to those in the upper basin. Some 300 miles of streams in the lower Wabash Basin of southwestern Indiana are affected by coal mining wastes. The adjacent Saline River Basin in Illinois has 60 miles of acid polluted streams. Other minor tributaries such as Pigeon Creek, Little Pigeon Creek and Cypress Creek show evidence of developing acid pollution problems.

Extensive acid mine drainage pollution exists in the lower Green River Basin of western Kentucky. The western portion of the basin, principally the Pond River and Pond Creek watersheds, commonly exhibits high acidity concentrations. Virtually the entire Tradewater River Basin is extensively polluted by acid mine drainage. The Green and Tradewater Basins have been reported to receive a combined total of 231 tons per day of mine acid.

Figure 8 shows the stream areas of the Ohio River Basin affected by acid mine pollution.

Corrective Measures-Acid Mine Drainage

Corrective action on abandoned mines presents a serious financial and administrative problem because many of the mined out areas are no longer under the control of responsible coal operators. No entirely satisfactory and economical method of eliminating this source of pollution has yet been developed.

Many of the states have or are now considering legislation that bring the coal operations under stream pollution regulatory authority. The Federal Water Pollution Control Administration has initiated demonstration projects to determine the relative effectiveness and cost of varied acid pollution control and prevention measures. The measures to be tried include sealing the mines against air, backfilling abandoned tunnels with mine wastes, diversion of surface drainage to prevent infiltation into the mines, concrete grouting to plug openings caused by settling of unsupported rock formations, chemical grouting to reduce soil permeability, and reclamation (by reshaping the contour and by revegetation) of areas grossly disturbed by strip mining. Where the pollution control or prevention measures mentioned above are not feasible from an engineering or economic viewpoint, consideration should be given to the feasibility of buffering or otherwise treating of acid water.

Heat Pollution Problems

Heat pollution caused by the return of cooling water from both industrial and power plant sources are now creating problems of very high termperatures in some parts of the basin. Increasing temperature diminishes the amount of oxygen that water can hold in solution. Consequently heat introduces additional pollution, because these waters are rendered less capable of assimilating oxygen-demanding pollution, or to support fish life.

Power Appendix I to the Corps report shows a total generating capacity of 28,000 megawatts of installed capacity of thermal power plants. This is expected to increase by a factor of 2.7 times by 1980. Unless controls are effected this could mean an increase in heat pollution of more than 200 percent in the next 15 to 20 years.

Heat pollution can be effectively reduced by careful planning in the location of heat-producing plants, the use of control measures such as recirculation, cooling towers and spray ponds, and by the substitution of air cooling methods where practical.

The present thermal power plants are grouped around areas that have the largest load demand. Some of the major groupings of existing thermal power plants in the basin are: the Allegheny, Monongahela and Main Stem Ohio River in the Pittsburgh area; the Kanawha River in the Charleston area; the Scioto River in the Columbus area; Miami River at Dayton; White River at Indianapolis; and Ohio River Main Stem in Evansville, Louisville and Cincinnati areas.

The Charleston, Columbus, Dayton and Indianapolis areas are also areas of large residual waste loads and are projected to exceed the stream assimilative capacity after secondary treatment and storage. The heat loads from these thermal power plants could intensify the organic pollution problem during the low flow periods.

The main stem plants do not appear to be problem areas at this time as sufficient dilution water is available to absorb the heat loads. With provision for treatment of heat loads, wastes, and flow regulation, thermal pollution should not present problems.

The Mahoning River of the Beaver River Basin has a complex combination of heat (thermal power and industrial) and organics from municipal and industrial wastes to the stream. In addition to industrial process cooling, there is an installed capacity of 450 megawatts in thermal power plants. Flow regulation from existing reservoirs and those under construction will provide about 515 cfs firm flow in the stream. Flows in the order of 875 cfs will be required by 2020 to maintain maximum temperatures of 93°F and assimilate organic wastes after adequate treatment. It is doubtful if flows of this magnitude can be accomplished; therefore, it will be necessary in this basin to examine other ways of further reducing waste and heat loads to the stream.

Chloride Pollution Problems

There are two areas of the Ohio River Basin where chloride contamination is an extensive or serious problem. One of these is the Muskingum River Basin. Due to industrial operations in the Barberton area, oil field brines, and salt mining in Stark and Summit Counties, there are high chloride concentrations in the Tuscarawas River and in the Muskingum River. Other streams affected are Oil Creek, Nimisila Creek, Chippewa Creek, and a portion of the old Ohio Canal.

The lower reaches of the Patoka River; Bonpas Creek, Illinois; Big Creek, Indiana; Embarrass River; and Little Wabash Rivers in the southern part of the Wabash River Basin receive oil field brines and wastes. The southeastern corner of Illinois in the Wabash Basin produces about 75 percent of the total oil from Illinois wells.

Lesser problems exist in smaller areas of several tributary basins. Paint Fork of Big Sandy River is contaiminated by oil field brines, as is the lower reach of Rough River, a tributary of Green River. Several small tributaries of the Licking River in Magoffin,

Estill, Lee, Powell, and Wolfe Counties also receive oil field brines. There is a similar problem in Morrow County, Ohio, in an area tributary to the Scioto River.

Taste and Odor Problems

Taste and odor problems are observed in several parts of the Ohio River Basin. Notable areas are the Kanawha River, the Beaver River and the main stem of the Ohio River. Tastes and odors are caused in many instances by organic compounds such as phenols, napthalene and oils, and in other instances by putrescible organic matter that has been flushed out by either rapid river rises or emptying of tanks and pits to hold settleable matter.

The solution to those problems is tighter in-plant controls to eliminate waste spillage containing taste and odor causing compounds. In industry this can be controlled by closed system processes where these compounds exist. More difficult to control are waste treatment plant effluents containing these products on an irregular basis.

Pollution Caused Fish Kills

Stream pollution limits the development of fishery resource potential of the Ohio Basin. In Appendix G, Fish and Wildlife, it is noted that pollution has reduced the stream mileage of potentially fishable waters by as much as 47 percent in Pennsylvania, 9 percent in West Virginia, and to lesser degrees in all other basin states. The Fish and Wildlife Service's study indicates the need for additional sport fishing habitat to provide for 3 million angler days annually by 2010.

Fish kill reports are an effective indicator of trouble areas in the Ohio Basin. They can create an awareness of areas that need further detailed investigation and corrective action to avoid more serious problems.

Major causes of fish kills are municipal, industrial, and agricultural pollution causing depressed dissolved oxygen conditions; the introduction of toxic substances generally considered as, but not limited to pesticides, herbicides, or toxic industrial wastes to include mine water wastes; and thermal pollution which raises the biological activity while depressing the needed dissolved oxygen.

During the year 1965, there were fish kills reported in 11 subareas of 13 in the Ohio River Basin with a total of 1,244,000 fish killed. One kill alone accounted for the death of over 600,000 fish. This was attributed to pesticide sprayed by an airplane and was the fifth worst fish kill in the United States that year. The following tabulation is given to show the relative amounts of fish killed due to various causes in the Ohio River Basin. The fish kill of 600,000 was not included in the calculations because it would distort the weight of each of these causes.

Source of Pollution	% killed in 1965
Chemical, Paper, Metal and Petroleum Processing	42
Mining Activities	19
Municipal Sewage	16
Food Processing	9
Other Agricultural Activities	6
Sprays - Poisons	5
Heat 1/	2
Transport Industries 2/	1

The most frequent cause of fish kills was due to municipal sewage, while, as can be seen in the previous tabulation, industrial wastes killed the greatest numbers of fish.

These types of pollutants are not the only cause of fish kills. High sediment loadings due to erosion, a cause of poorly managed land resources, can coat the stream bed with shifting silt which kills young fish and also the feed for fish. This type of pollution is quite likely to cause changes in the ecological environment, affecting the numbers and species of organisms found in an area. Further information on sediment can be found in Appendices on F, Agriculture, and C, Hydrology.

1/ Thermal pollution - generally attributed to power plant or industrial water used for cooling purposes.

2/ Generally considered as pipeline breaks, or truck or railroad accidents which dump pollutants into water bodies.

TABLE 6

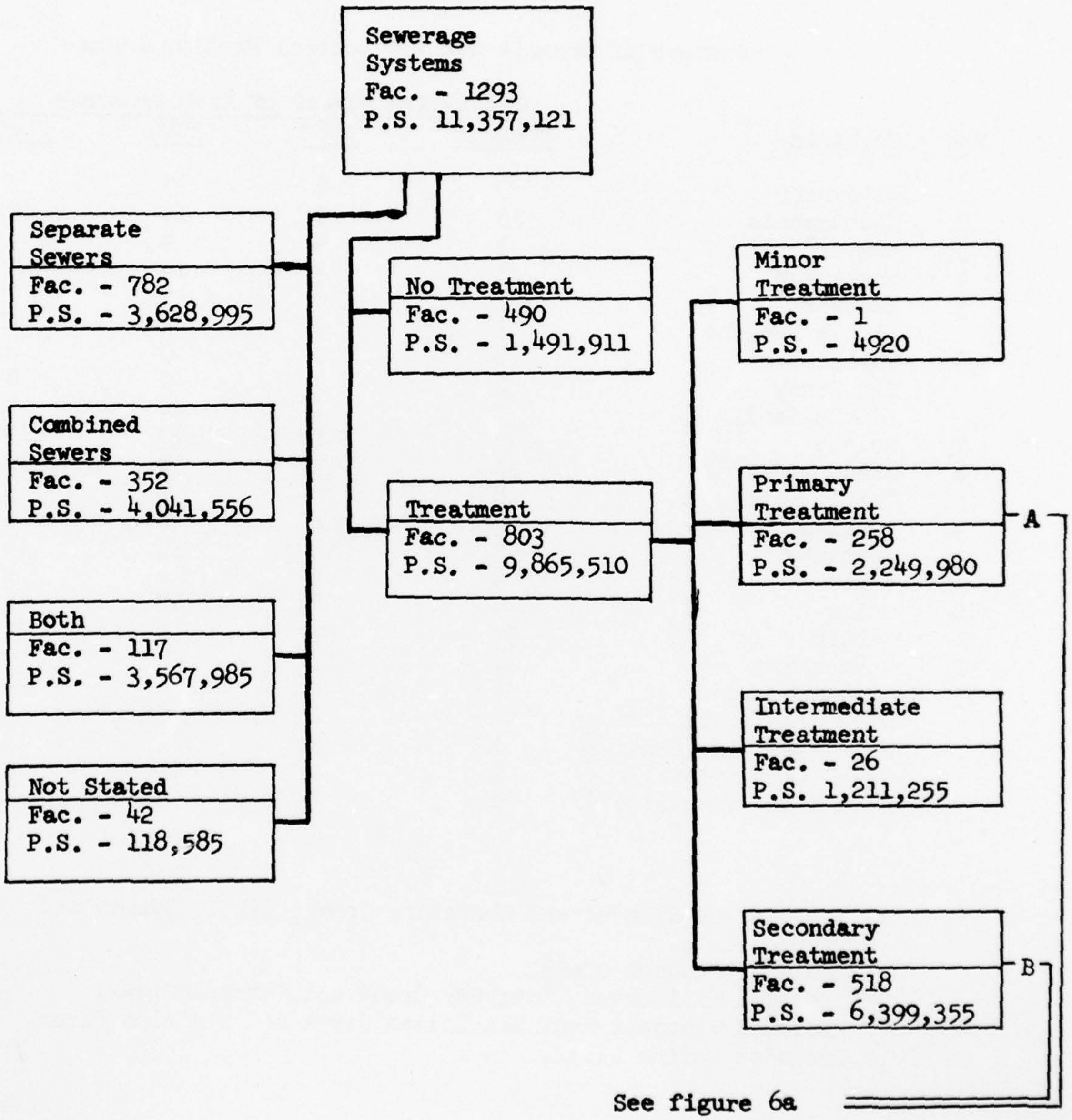
OHIO RIVER BASIN

Summary of Organic Quality Control Problem Areas

No.	Subbasin	Cumulative Number of Problem Areas			
		Present	1980	2000	2020
1	Allegheny	5	6	7	7
2	Monongahela	15	15	15	15
3	Beaver	1	4	4	4
4	Muskingum	11	13	14	14
5	Kanawha	3	6	7	7
	Little Kanawha	1	2	2	2
6	Guyandotte	0	0	0	0
	Big Sandy	0	0	0	0
	Little Sandy	0	0	0	0
7	Scioto	17	18	19	19
8	Great Miami	11	15	18	18
	Little Miami	8	8	8	8
9	Licking	6	6	6	6
	Kentucky	13	14	14	14
	Salt	9	9	9	9
10	Green	9	16	18	18
11	Wabash	50	52	53	53
12	Cumberland	17	17	18	19
13	Main Stem Upper 1/	8	8	8	8
	Main Stem Huntington 2/	1	1	1	1
	Main Stem Cincinnati 3/	3	3	3	3
	Main Stem Louisville 4/	2	2	2	2
	Main Stem Evansville 5/	1	1	1	1

1/ Includes Hocking River, Chartiers Creek, Little Beaver and Robinson Run.
2/ Includes Raccoon Creek.
3/ Includes Mill Creek, Laughery Creek and Tanners Creek.
4/ Includes Pleasant Run, Big Indian Creek and Big Blue River.
5/ Includes Saline River.

SUMMARY OF MUNICIPAL SEWERAGE AND TREATMENT
FACILITIES IN OHIO RIVER BASIN-1962



Facilities - Fac.
Population Served - P.S.

Figure 6

SUMMARY OF MUNICIPAL SEWAGE TREATMENT IN OHIO RIVER BASIN-1962

A — Primary Treatment
Fac. - 258
P.S. - 2,249,980

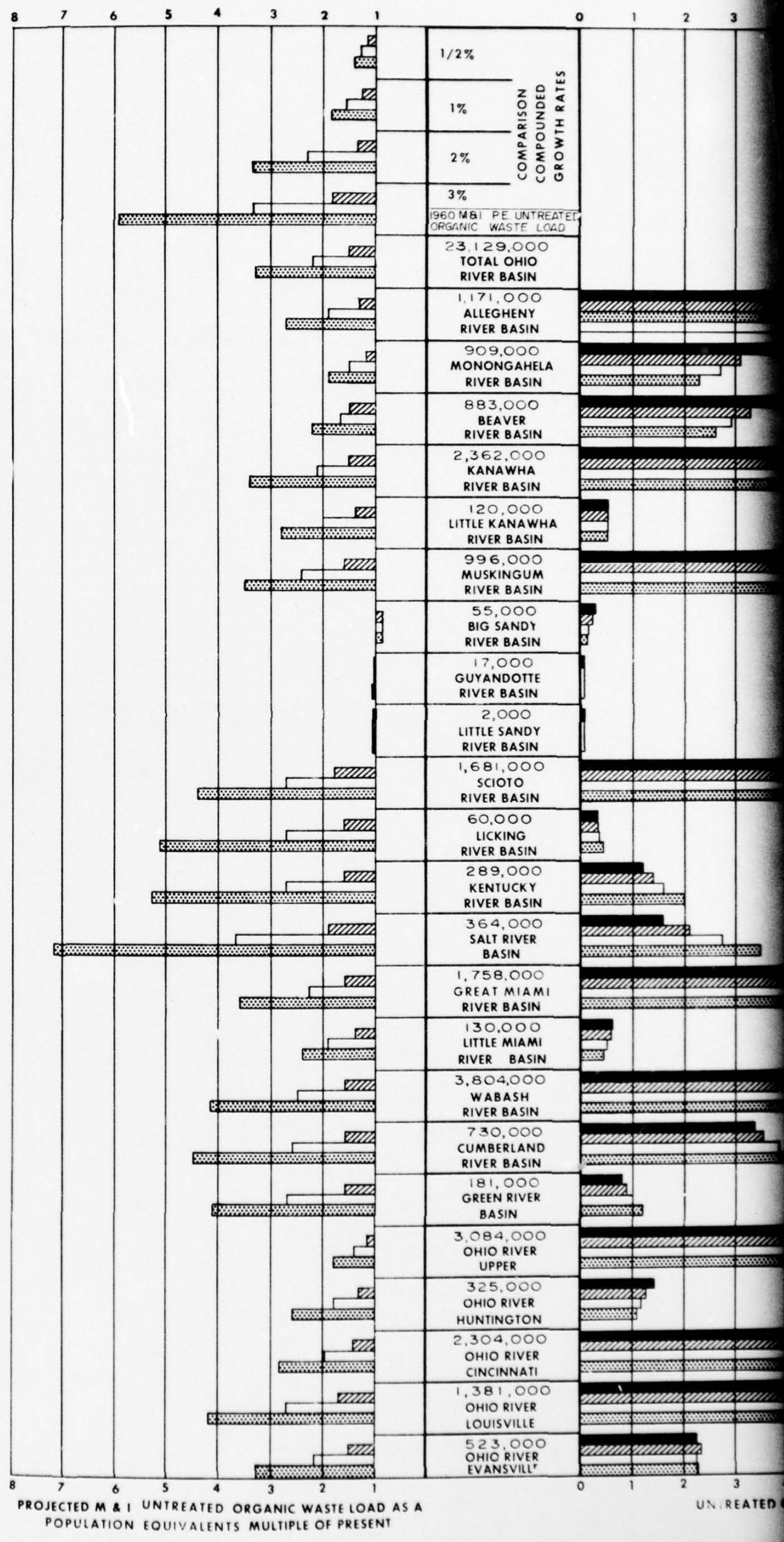
PROCESS	Number Facilities	%	Population Served	%
Septic Tanks	30	11.6	37,970	1.7
Imhoff Tanks	115	44.6	439,570	19.5
Mechanically Cleaned Tanks	104	40.3	1,746,775	77.6
Plain Hopper Bottom Tanks	5	1.9	20,700	.9
Tanks - No details	3	1.2	2,985	.2
Others and Unknown	1	.4	2,000	.1

B — Secondary Treatment
Fac. - 518
P.S. - 6,399,355

PROCESS	Number Facilities	%	Population Served	%
Activated Sludge	132	25.5	4,184,650	65.4
Extended Aeration	43	8.3	108,865	1.7
Trickling Filters-Standard Rate	194	37.5	1,356,880	21.3
Trickling Filters-High Rate	98	18.9	636,410	9.9
Intermittent Sand Filters	25	4.8	33,040	.5
Application to Land	3	.6	1,225	.1
Stabilization Ponds	15	2.9	18,415	.3
Others and Unknown	8	1.5	59,870	.9

Facilities - Fac.
Population Served - P.S.

Figure 6a



8 7 6 5 4 3 2 1
0 1 2 3
1/2%
1%
2%
3%
COMPARISON COMPOUNDED GROWTH RATES
1960 M&I P.E. UNTREATED ORGANIC WASTE LOAD
23,129,000 TOTAL OHIO RIVER BASIN
1,171,000 ALLEGHENY RIVER BASIN
909,000 MONONGAHELA RIVER BASIN
883,000 BEAVER RIVER BASIN
2,362,000 KANAWHA RIVER BASIN
120,000 LITTLE KANAWHA RIVER BASIN
996,000 MUSKINGUM RIVER BASIN
55,000 BIG SANDY RIVER BASIN
17,000 GUYANDOTTE RIVER BASIN
2,000 LITTLE SANDY RIVER BASIN
1,681,000 SCIOTO RIVER BASIN
60,000 LICKING RIVER BASIN
289,000 KENTUCKY RIVER BASIN
364,000 SALT RIVER BASIN
1,758,000 GREAT MIAMI RIVER BASIN
130,000 LITTLE MIAMI RIVER BASIN
3,804,000 WABASH RIVER BASIN
730,000 CUMBERLAND RIVER BASIN
181,000 GREEN RIVER BASIN
3,084,000 OHIO RIVER UPPER
325,000 OHIO RIVER HUNTINGTON
2,304,000 OHIO RIVER CINCINNATI
1,381,000 OHIO RIVER LOUISVILLE
523,000 OHIO RIVER EVANSVILLE
PROJECTED M & I UNTREATED ORGANIC WASTE LOAD AS A POPULATION EQUIVALENTS MULTIPLE OF PRESENT

OHIO RIVER BASIN FRAMEWORK STUDY

COMPARISON OF PRESENT & PROJECTED RAW WASTE LOADS (POPULATION EQUIVALENT)

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLUTION CONTROL ADMINISTRATION

OHIO RIVER BASIN PROJECT

CINCINNATI OHIO

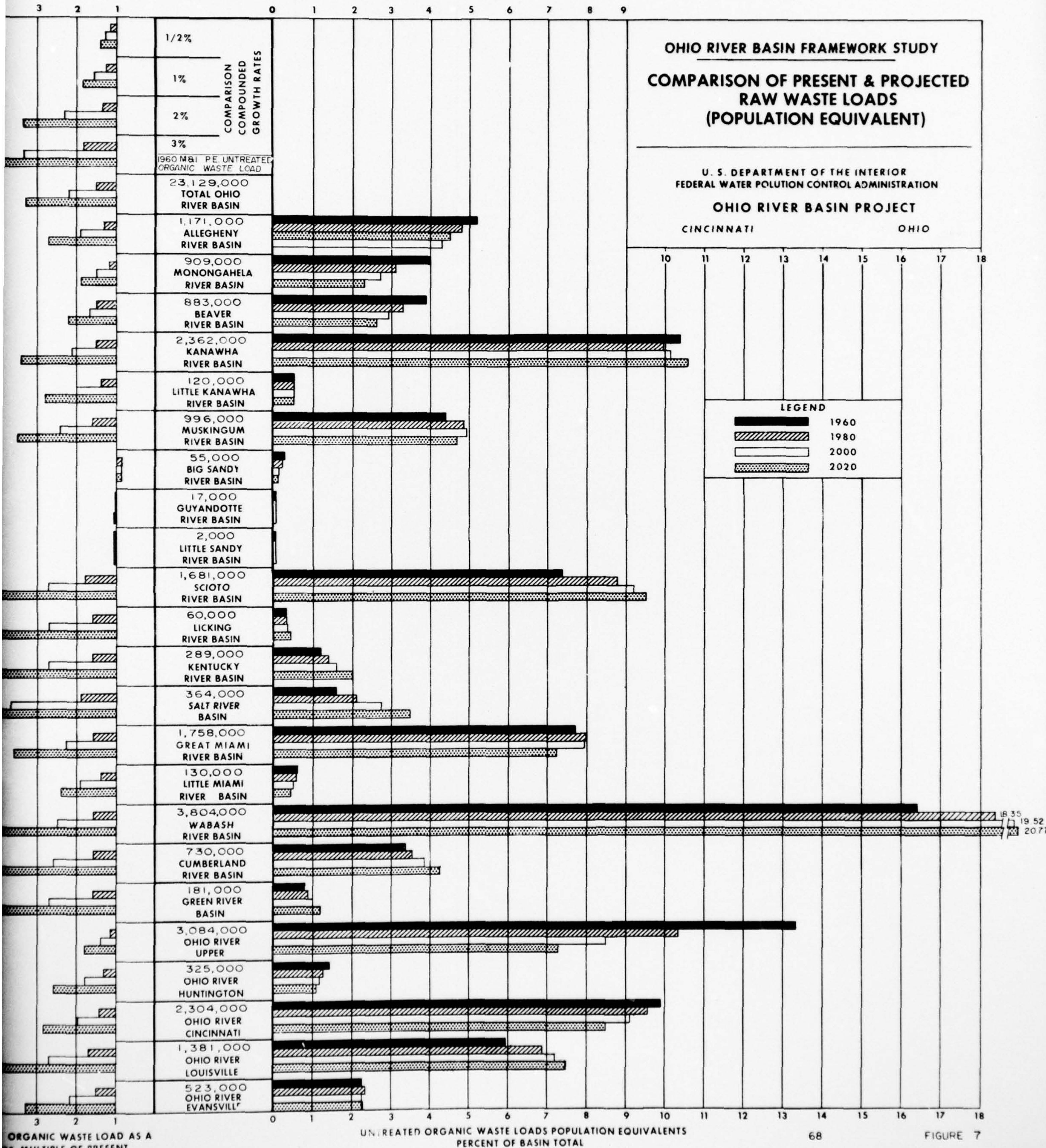
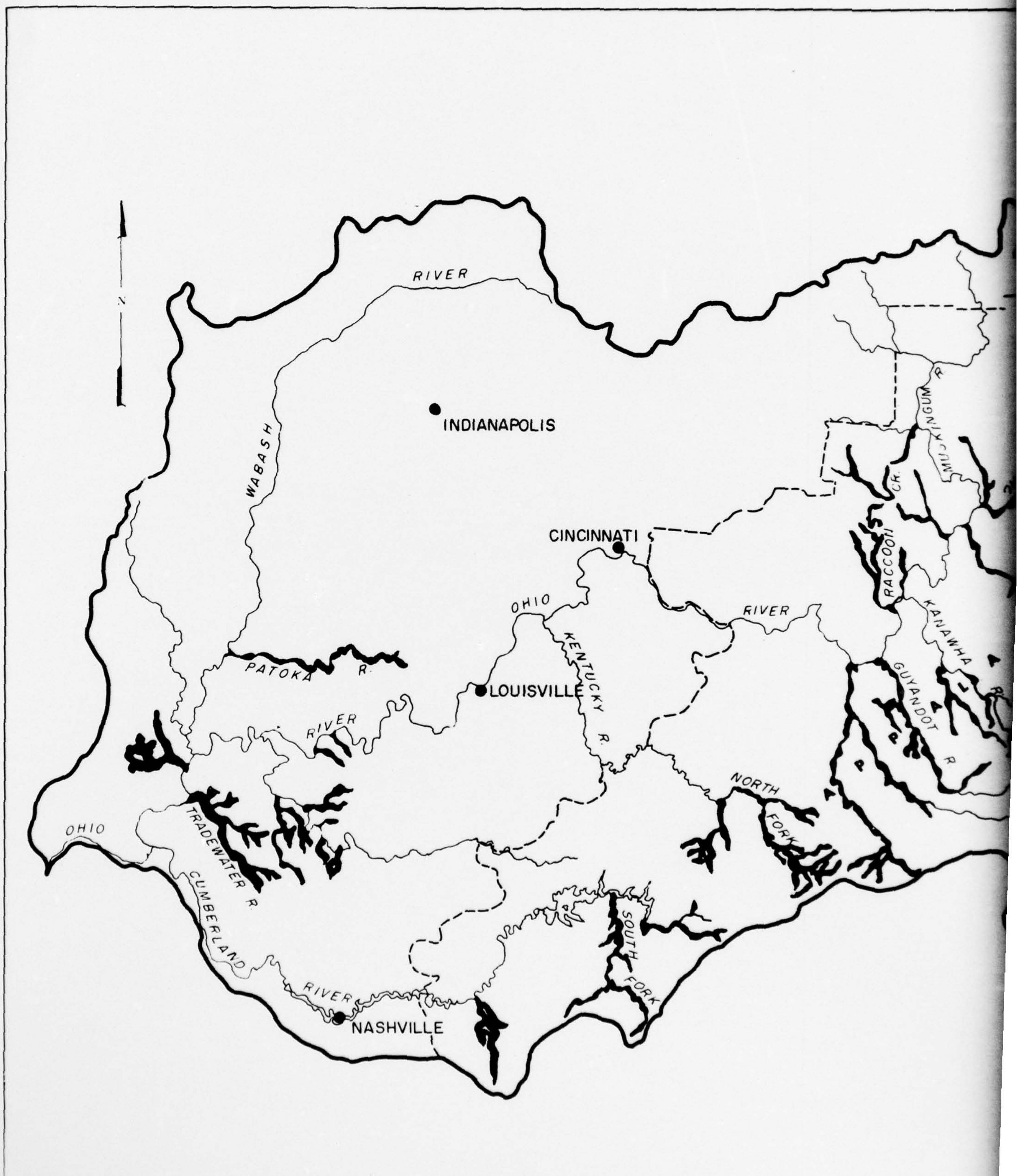


FIGURE 7


N
RIVER
WABASH
INDIANAPOLIS
CINCINNATI
OHIO
RIVER
KENTUCKY R.
LOUISVILLE
PATOKA R.
RIVER
MUSKINGUM R.
RACCOON CR.
KANAWHA
GUYANDOT R.
NORTH FORK
SOUTH FORK
OHIO
TRADEWATER R.
CUMBERLAND
RIVER
NASHVILLE

OHIO RIVER BASIN FRAMEWORK STUDY

ACID MINE DRAINAGE POLLUTION

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIG 8

V GENERAL RECOMMENDATIONS

1. Secondary treatment or appropriate waste reducing processes should be applied to all municipal and industrial wastes. All settleable solids that will form putrescent or otherwise objectionable sludge deposits should be removed; oil, scum, floating materials and substances producing color and odor should be removed to such degrees required to prevent unsightly or deleterious conditions; all substances that are toxic or harmful to human, animal, plant or aquatic life by themselves or in combination should be removed; heated discharges should be sufficiently cooled before discharge to prevent stream impairment for other uses; and harmful bacteria should be reduced in sufficient number to allow intended stream uses.

2. Proposed new sewerage facilities should be designed to prevent the necessity of by-passing untreated wastes. Combined storm and sanitary sewers should be prohibited in all areas that are to be developed, and eliminated in existing areas where the resulting improvement would justify expenditures. Existing combined sewer systems should be patrolled and flow-regulating structures adjusted to convey the maximum practicable amount of combined flows to and through treatment plants. This is particularly necessary in areas where current waste loads are producing serious stream degradation.

3. Storage for streamflow regulation should be provided to increase streamflow and waste assimilation during periods of low flow, however emphasis should be placed on improved treatment rather than relying on flow regulation alone.

4. Detailed investigations should be made of the practicability and costs of advanced waste treatment methods, diversion of wastes or other means of water pollution control in all designated problem areas.

5. A program of correcting acid mine drainage at the source in both active and "abandoned" mines should be promoted. Legislation providing for controlling mine discharges and reclamation of strip mine areas should be advanced.

6. Specific methods of brine waste disposal from oil fields and industrial processes should be recommended and programs developed to implement the recommendations.

7. Off-stream cooling methods should be provided in areas where heat pollution or heat aggravated pollution problems are or are likely to be significant.

8. Appropriate controls of discharges of taste and odor producing substances should be provided.

9. Prevention of discharges of toxic concentrations even where long-term effects on health are unknown must be achieved.

10. Re-evaluate operation and control of existing reservoirs to best meet the needs of flow regulation for water quality control. Feasibility of reservoir regulation by automatic water quality data monitoring feedback should be included in such re-evaluation. Streamflow forecasts formulated and issued by the Environmental Science Services Administration through its Weather Bureau Offices should be considered in reservoir operation for quality control.

11. Careful consideration should be given to the effect of hydropower installations on water quality in both large resource development projects and navigation structures.

12. Providing storage in reservoirs can have both beneficial and degrading effects on water quality in a reservoir. Some possible effects are thermal stratification, reduced turbidity, increased plankton and algae growth, reduced coliform organisms, decreased dissolved oxygen in stratified water, possible increase in iron and manganese in bottom waters, and general smoothing or equalizing effects on mineral quality. Reservoirs should be operated in a manner to decrease or eliminate the degrading effects. Multiple outlet structures in projects should be considered wherever appropriate to provide water of good quality for flow regulation.

13. State or Interstate planning agencies should be established to develop water quality programs for entire river basins.

ALLEGHENY RIVER BASIN

Subbasin Area
No. 1

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I SUMMARY

Municipal and Industrial Water Supply Problems

The next decade should see planning for the continuation of adequate water supplies by many of the municipalities of the Allegheny River Basin. However, only one community is indicated by the study as having a present need. This community is Blairsville, Pennsylvania, and needs can probably best be met from a surface source other than the Conemaugh River.

Six of the 13 water supply problem areas will have needs by 1980 according to the projections developed in this study. Increased development of surface water sources or valley fill alluvium should supply the requirements of Titusville, Kane, Port Allegany, and Warren, Pennsylvania. Kane, Pennsylvania, may have to augment present ground sources from surface storage.

In the central and southern sections of the basin, Johnsonburg, and Indiana, Pennsylvania, are the major areas of projected future need. There are also 4 smaller communities in the group of 13 mentioned above. These smaller communities are generally in the headwaters of the Conemaugh River and should be able to meet their needs by impounding flows from small tributary drainage areas. Acid mine drainage is often a factor in deciding on a source of water supply in this area. Requirements at Johnsonburg are largely industrial and may be adequately met from surface development.

Valley fill alluvium should serve as an adequate source of future water for Union City, Pennsylvania, which is outside the Projective Economic Study area. Olean, New York, may need to expand its supply by 2000 and should be able to find ample supplies in the Allegheny River.

Much of the industrial development in the basin occurs in the Allegheny River valley itself in Westmoreland and Allegheny Counties. Surface flows should be ample to meet new industrial requirements, including at least a doubling of the heat load from thermal power plants provided new sites are carefully chosen. Industry in the northwestern section of the basin is fortunate in having access to large ground water resources.

Water Quality Control Problems

All wastes are assumed to have been given secondary treatment or equivalent reduction before discharge to streams of the basin. Low flow regulation is considered the next likely measure in pollution control for most communities in this area. There are needs now for regulated low flows in Tunungwant Creek below Bradford, Pennsylvania; in Paint Creek below Windber, Pennsylvania and in Loyalhanna Creek below Latrobe, Pennsylvania. There will be a need for additional flows in French Creek below Meadville, Pennsylvania, by 1980 and in Two Lick Creek below Indiana, Pennsylvania, by 2000.

The Clarion River in its upper reach is subject to a heavy industrial residual organic waste load. Municipal and industrial waste treatment facilities in the area must continue to be properly operated in order for the existing plan of flow regulation to be effective.

Acid conditions caused by drainage from coal mining operations occur in many streams in the central and southern portions of the Allegheny River Basin. Slug acid discharges occur, causing wider variation in water quality over the base level otherwise expected. Drainage areas which have acid runoff and drainage are the Kiskiminetas-Conemaugh Rivers system, Clarion River, Crooked Creek, Redbank Creek, and Cowanshannock Creek.

Other localized problems occur below smaller communities but these are considered to be beyond the scope of this study.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Allegheny River rises near Coudersport in northwestern Pennsylvania. It flows westward and then northward into New York, then turns south near Salamanca, New York, and flows southwestward through Pennsylvania. It joins the Monongahela River at Pittsburgh to form the Ohio River. The total length of the Allegheny River is approximately 325 miles.

The basin embraces approximately 11,730 square miles in western New York and western Pennsylvania. It is about 175 miles long on a north-south axis and its maximum width is about 130 miles. About 1,965 square miles of New York and 9,765 square miles of Pennsylvania are in the watershed. Adjacent are the Great Lakes-St. Lawrence River Basin on the north, the Susquehanna River Basin on the east, the Monongahela River on the south, the Beaver River and an area draining directly to the Ohio River on the west. Table 1 lists the three counties in New York and the nineteen in Pennsylvania which lie partly or wholly in the watershed. Table 2 gives drainage areas and lengths of the Allegheny River and its major tributaries. Figure 1-1, page 1-38, shows the Allegheny River Basin.

Physical Features

The Allegheny River Basin is in the southern New York and Kanawha sections of the Appalachian Plateau physiographic province. The southern New York section represents a mature glaciated plateau of moderate relief. The Kanawha section represents a mature unglaciated plateau of fine texture with moderate to strong relief.

About 25 percent of the topography of the basin has been modified by the advance of the last continental ice sheets. The line of farthest advance crosses the northwestern part of the region running from just west of Franklin, Pennsylvania, to just east of Jamestown, New York. The topography of the glaciated area is generally that of rolling plains with gentle slopes. Many lakes and swamps have been formed on the glacial deposits because the post-glacial drainage has not had time to develop a

significant degree of integration. Below and to the east of the glacial advance, the topography displays moderate to strong relief. In the mountain upland and high plateau areas of the basin, the land is highly dissected by its drainage. For example, the Conemaugh River and Loyalhanna Creek gorges are over 1,000 feet deep. The highest points in the upland areas are above 2,500 feet in elevation.

There are eight reservoirs in the basin which have or will have storage of 25,000 acre-feet or greater. All but one of these are operated by the U. S. Army Corps of Engineers as part of the integrated system for control of floods in the Ohio River Basin. The exception is Piney Reservoir on the Clarion River operated for power generation. One large natural lake, Lake Chautauqua, is in the northern end of the basin. In addition, a number of small lakes and reservoirs serve recreational needs. Recreation areas located in the counties of Elk, Forest, Warren, and McKean Counties, Pennsylvania, have a total water area (in one or more bodies of water) of more than 100 acres.

Climate

The Allegheny River Basin has a humid continental climate modified slightly by its proximity to the Atlantic seaboard and to the Great Lakes. The climate is influenced predominately by air with a polar continental source in Canada. Frequent invasions of air originating in the Gulf of Mexico produce warm, humid weather during the summer and alternate periods of freezing and thawing in the winter. Farther north in the area and at higher altitudes, the growing season is reduced significantly. The average frost-free period at Jamestown is 144 days as compared to 176 at Pittsburgh.

Average annual precipitation shows a relatively wide variation. At Pittsburgh, it is about 36 inches, at Jamestown about 42 inches, and at Ridgway, on the eastern edge of the basin at a higher elevation, about 41 inches. Mean January temperatures are 31°F at Pittsburgh, 27°F at Jamestown, and 25°F at Ridgway. Mean July temperatures are 74°F at Pittsburgh, 71°F at Jamestown, and 68°F at Ridgway. The temperature variation is wider with altitude than with north-south distance.

Principal Communities and Industries

Table 3 lists populations of principal communities in the basin from 1910 to 1960. The Pittsburgh area and its industries are discussed as part of the Ohio River main stem drainage. Outside the Pittsburgh area, there are four major industry groupings which dominate manufacturing: primary metal products; electrical machinery, equipment, and supplies; fabricated metal products; and stone, clay and glass products.

In Jamestown, New York, principal products are metal office furniture, ball bearings, hand tools and washing machines. Olean industry contributes electronic components, chairs, cutlery and heating equipment. Thus, the principal industries in the New York part of the basin are fabricated metals and electrical machinery and equipment.

In the State of Pennsylvania, industry in major cities in the basin is diversified. Oil production, refining, and support industries center in Oil City with the addition of metal cans and glass bottles. Acetate fiber, heat treating furnaces, metal fasteners and tools are products of Meadville manufacturing. In Bradford, industrial products are oil field and farm machinery, pumps, valves, refrigeration equipment, corrugated boxes and cigarette lighters. Warren industry concentrates on heavy fabrication, and electrical parts including lamps and fuses. Manufacture of truck and railroad car bodies, boilers, mining machinery, and basic steel production are found in Franklin.

Johnstown industry contains basic steel, heavy steel fabrication, apparel manufacture, and refractory products. Laboratory instruments, industrial process controllers, sweaters, and tires are products of Indiana manufacturing. Carbon and graphite products, refrigeration and air conditioning, tools and machine tool accessories are output from Punxsutawney industry. There is a large pulp mill at Johnsonburg and a dye and pigment plant at Ridgway. DuBois, located in Clearfield County which is not included in the Projective Economic Study, produces rubber goods, food products, instruments, and other electronic components.

Basic steel and its derivatives are the primary industries in the Westmoreland County portion of the Allegheny River drainage area. There are blast furnaces, heavy castings and boiler production and porcelain and glass products made in Latrobe. Aluminum castings, shot steel, flat glass, and apparel are made in New Kensington. In Vandergrift, basic steel production, prefabricated house construction, and metal working industries predominate.

III WATER RESOURCES

Surface Water Resources

Quantity

Seven reservoirs are operated by the U. S. Army Corps of Engineers to control flood waters. Five of these are single purpose--those on Tionesta Creek, Mahoning Creek, Crooked Creek Conemaugh River, and Loyalhanna Creek. Allegheny Reservoir, under construction, and East Branch Clarion River Reservoir have supplemental storage for low flow stream regulation. Piney Reservoir on Clarion River is privately operated for hydropower generation. Data concerning these reservoirs are shown in Table 4.

Table 5 gives ranges of flow and unregulated design flow values for various stations in the basin. Higher sustained low flows would be expected of streams in the northwestern section of the basin than in the area to the south of the Clarion River because of the effects of ground water storage.

Quality

Generally, the natural quality of water in the upper reaches of the Allegheny River Basin is good. In one recent year, the solids concentrations, as estimated from measurements of specific conductance, ranged from about 40 to 800mg/l in daily samples at Red House, New York, but concentrations most of the time were less than 300 mg/l. Chloride concentrations over the same time ranged from 7 to 308 mg/l with only 25 daily values greater than 100 mg/l. Few data are available concerning hardness and sulfate concentrations at this station. However, major forms of pollution are associated with the extractive industries. Oil production in Warren and Venango Counties has led to pollution by brines and other oil field wastes. Long years of coal mining have left quite a number of streams contaminated by mine drainage containing sulfuric acid and iron.

A major fraction of the acid load occurs in the Kiskiminetas drainage. Acid streams in this drainage area are Conemaugh and Little Conemaugh Rivers, Loyalhanna Creek, and Blacklick Creek. Some other acid streams in the Allegheny watershed are Clarion River, Crooked Creek, Redbank Creek, and Cowanshannock Creek.

In the upper reaches of the Clarion River, the primary sources of biochemical oxygen demand are the wastes from a paper mill and an organic dye company. The lower reach of the Clarion River has color, taste and odor problems.

The Kiskiminetas River enters the Allegheny River 30 miles above Pittsburgh and is the chief source of mineral pollution in the lower Allegheny. Over the period 1947-1951, considerable data were accumulated dealing with water quality in the Kiskiminetas. These data present a picture of a highly acid stream which has a marked influence on the quality of water mixed with it in the Allegheny. Weekly samples were taken of the Kiskiminetas and the Allegheny above and below the confluence by the Allegheny County Sanitary Authority in 1949. Analyses of 42 sets of these samples over a broad range of flows are revealing. The low flow was 320 cfs and the highest was 20,700 cfs. The maximum pH value of any sample from the Kiskiminetas was 4.7. Almost all of the 42 sets of samples were in groups of three at two of the three locations. On the Kiskiminetas, the median pH ranged from 3.1 to 4.5. There was a corresponding decrease in pH in the Allegheny. Above the confluence, pH values ranged from 6.7 to 7.7 with three-fourths of the results greater than or equal to 7. Below the confluence, medians of the group of three were from 4.6 to 7.1 with about 40 percent less than 6.5. Total acidity carried by the Kiskiminetas has been estimated from U. S. Geological Survey data during water years 1947 to 1951. The mean acidity load based on 10 day composite samples was 908 tons per day and the range of loads was from 212 to 3,553 tons per day.

At low flows, sulfate concentrations in the Allegheny River increase by 40 mg/l, from 40 mg/l to 80 mg/l, by mixing with the Kiskiminetas River waters. Several above-below pairs showed increases of 100 to 160 mg/l. At higher flows, the increase was on the order of 10 to 40 mg/l. Median concentrations of sulfate

ion in the Kiskiminetas itself were over the 250 mg/l recommended by the U. S. Public Health Service for drinking water supplies in more than 60 percent of the sets of samples. Total iron concentrations were also quite high, with the median values ranging from 1.7 to 28 mg/l. One set of samples taken during a temporary rise in flow after local rain resulted in a reported concentration of 169 mg/l. Acid loads are also quite high in times of flushouts such as this. This unevenness in concentrations is a major source of problems to the 10 public water supplies using the Allegheny River between its confluence with the Kiskiminetas River and its confluence with the Monongahela River, not only in terms of acidity, but also with respect to hardness and manganese.

Total hardness in the Kiskiminetas at Leechburg is also quite high. At flows less than 500 cfs, hardnesses range from 350 mg/l to 700 mg/l, while at 5,000 cfs, the concentrations range from 110 to 160 mg/l. Even at the higher flows, it may be desirable to treat this water for hardness before domestic use since the hardness is primarily noncarbonate.

In a recent year at Pittsburgh in samples from the Allegheny River, total hardness ranged from 60 to 280 mg/l, sulfate ranged from 45 to 249 mg/l, chlorides ranged from 10 to 46 mg/l, and pH values were from 3.7 to 7.2. The low pH value was one of two during the year which were less than 6 out of 43 samples taken.

Ground Water Resources

Quantity

A discussion of ground water resources in detail has been prepared by the U. S. Geological Survey.[1/] The following condensation is excerpted from that discussion.

Four of the principal aquifers of the basin, sources for possible future development in order of decreasing potential, are as follows:

1. Outwash deposits, especially in the valleys of streams tributary to the Allegheny River from the northwest in Crawford, Venango, Erie, and Warren Counties, Pennsylvania.

2. Glacial and alluvial sediments along the Allegheny River valley itself, in the valleys of tributaries above Salamanca, New York, and tributary valleys entering from the east between Tionesta, Pennsylvania, and Salamanca, New York.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

3. Sandstone units of the Pocono Formation where it forms the bedrock surface in the northern third of the basin and southward where it dips under younger rocks.

4. Sandstone strata of Pennsylvania age in the Pottsville, Allegheny, and Conemaugh Formations throughout most of the Pennsylvania section of the basin, and especially along the southwestern divide.

Yields from wells in the outwash deposits commonly range from 100 to 2,000 gpm. These high yields are possible because the outwash is permeable and recharge occurs readily from the perennial streams which flow down the glacial valleys.

Wells in the alluvial valley of the Allegheny River yield from 100 to 1,000 gpm. The alluvium ranges in thickness from 100 feet at Franklin to 65 feet at Pittsburgh, and numerous wells pump from this alluvium in Warren, Franklin, Ford City, and Pittsburgh.

In western Pennsylvania, the Pocono sandstones are widely referred to as the "Mountain Sands." Municipal and industrial wells in this formation have yielded 300 to 2,100 gpm. One spring near Meadville, issuing from this same formation, was reported to flow at 200 gpm.

Quality

Waters from the glacial outwash deposits are reported to have hardness[1/] values ranging from 36 to 280 mg/l, sulfate concentrations less than 120 mg/l, chloride concentrations less than 50 mg/l, and 0.01 to 2.5 mg/l of iron. It would be necessary in most cases to remove iron from these waters and many uses would require softening as well.

Waters from the Allegheny River valley alluvium have hardness values from 120 to 280 mg/l, 15 to 350 mg/l of sulfate, 30 to 90 mg/l of chloride, and 0 to 3 mg/l of iron.

Aquifers of the Pocono Formation yield waters having 10 to 170 mg/l hardness, 4 to 100 mg/l sulfate, 2 to 160 mg/l chloride, and 0 to 6.8 mg/l iron. Here as in most locations in the basin, iron removal would be desirable before the water is put to domestic use. Where the Pocono is encountered at depths greater than 200 feet, the water is likely to be more highly mineralized.

1/ Total hardness expressed as $CaCO_3$.

Yields from the sandstones of the Allegheny, Conemaugh, and Pottsville Formations are not as high as those discussed above, though they are adequate for domestic and small municipal and industrial supplies. Waters from all three formations show similar quality to those discussed above except for possible higher iron content.

IV THE ECONOMY

The Allegheny subarea of the Projective Economic Study lies entirely within Pennsylvania and is roughly coextensive with the middle and upper reaches of the Allegheny River drainage basin. To facilitate future estimates of water requirements and waste loads, the subarea has been divided into two minor areas, A-1 and A-2. The A-1 area includes the five northern counties of the subarea, and A-2 the seven southern counties. The subarea is entirely within the region designated as Appalachia. The upper reaches of the Allegheny River watershed extend beyond the northern boundary of economic Subarea A and encompass about one-half of Erie County in Pennsylvania, about three quarters of Chautauqua and Cattaraugus Counties, and one-fifth of Allegany County in New York. The latter three counties (see Tables 6b and 7b) are the subject of a supplemental economic study prepared by the Division of Water Resources, New York State Conservation Department. Tables 6a and 7a list the 12 counties of the Projective Economic Study. These counties are also shown on Figure 1-1, page 1-38.

Economic Profiles

Minor Area A-1

Minor area A-1, located entirely within the State of Pennsylvania, had a 1960 population of 247,900 and contained four larger cities, all with populations between 14,000 and 18,000. These cities are Bradford, Meadville, Oil City, and Warren. Per capita personal income for this minor area equaled $1,642 compared to $1,855 for the State of Pennsylvania.

Manufacturing was the largest employment category in the area. There was no significant change in plants of 100 workers or over between 1958 and 1964, but there has been an increase in smaller plants. The most important manufacturing industries are machinery (including electrical machinery), other durables, other nondurables, and fabricated metals. Two thermal power generating plants are located in the area, one at Warren, Pennsylvania, with a capacity of 73.4 megawatts, and one at Oil City, Pennsylvania, with a capacity of 16 megawatts.

Agricultural employment decreased by one-half between 1950 and 1960 while the value of farm products sold increased \$5.5 million over the 1954 figure to \$25 million by 1959. Dairy products accounted for 64 percent of this total figure with livestock products accounting for another 16 percent. Approximately 115 acres were under irrigation in 1959.

Crude oil is the most important mineral extracted in the area. In 1960, 5.3 million barrels of crude oil were produced which was 87.5 percent of total State production. Coal was produced only in Venango County, amounting to 588,000 tons or less than 1 percent of the total production in the State of Pennsylvania.

Minor Area A-2

Population in minor area A-2, also located entirely within Pennsylvania, was 557,200 in 1960, with the largest cities being Johnstown and Indiana with populations of 53,950 and 13,000 respectively. Two counties, Cambria and Somerset, compose the Johnstown Standard Metropolitan Statistical Area. Fifty percent of total area population reside in these two counties and have a per capita personal income of \$1,371 compared to \$1,494 for the remaining five counties and \$1,855 for the State of Pennsylvania.

Manufacturing is the most important employment category. The most important manufacturing industries are primary metals, other durables, machinery (including electrical machinery), and apparel. The manufacturing establishments are fairly well distributed throughout the area. No significant change took place in the number of plants with 100 workers or over between 1958 and 1964. However, manufacturing employment is projected to increase throughout the total study period.

Two thermal power plants are located in the area, one at Armstrong with a generating capacity of 326.4 megawatts and one at Johnstown with a capacity of 74.5 megawatts. A 575 tons per day pulp plant is located at Johnsonburg.

Bituminous coal extraction is of paramount importance in the area, with crude oil production next in importance. In 1960, 21.4 million tons of coal were produced and 87.3 thousand barrels of oil were produced, representing 32.7 percent and 1.5 percent, respectively, of the total production in the State of Pennsylvania.

However, total mining employment declined from 38,300 in 1950 to 13,400 in 1960, or a decline of 65 percent. The decrease in mining employment in Cambria and Somerset Counties is a major reason for the relatively low personal per capita income in 1960.

Agricultural employment declined from 12,600 in 1950 to 8,500 in 1960. However, value of total farm products sold increased from $36 million in 1954 to $44 million in 1959, 46 percent of the 1959 figure being dairy products. Land irrigated increased from 350 acres to 550 acres between 1954 and 1959.

New York State Counties

As shown in Table 6b, total population for the 3-county area in 1960 was 269,600 with three large cities of these counties located in the Allegheny River drainage area. These cities are Jamestown in Chautauqua County with a population of 41,000, and Salamanca and Olean in Cattaraugus County with populations of 8,500 and 21,900 respectively.

Eighty manufacturing establishments having 100 employees or more were located in these counties in 1964. The most important manufacturing industries are furniture, lumber, and wood products, primary and fabricated metals, other nondurables, machinery (including electrical machinery), and food and kindred products. One thermal power generating plant with a capacity of 57.5 megawatts is located at Jamestown, New York.

Agricultural employment decreased about 40 percent between 1950 and 1960. The value of farm products sold was about $48 million in 1960. Dairy products accounted for 60 percent, livestock products accounted for 13 percent, and fruit accounted for 11 percent of this total figure.

Although county figures are not available at this time, it is known that there is some oil extraction in Cattaraugus County.

Projected Population and Industrial Activity

Subarea A

Population is projected in Subarea A to increase from 805,100 in 1960 to 922,500 in 1980 and to 1.3 million by 2020. Whereas the area population amounted to 4.2 percent of Ohio River Basin population in 1960, it is projected to have 4 percent of Ohio River Basin population by 1980 and 3.7 percent by 2020.

Agricultural output in Subarea A as projected in the Projective Economic Study is expected to decline slightly from $134 million in 1960 to $129 million by 1980 and then increase to about $172 million by the year 2010.

Manufacturing output is projected to increase steadily from $2 billion in 1960 to 4.4 times this figure or approximately $8.8 billion by 2010.

Table 7a shows 1960 manufacturing output, total employment, and manufacturing employment. Projections to 1980, 2000, and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Allegheny subarea in the Projective Economic Study, ten other counties have land area within the basin. These counties are listed in Table 8. Three of these counties are in New York State and are discussed in the following paragraph. The remaining counties are in Pennsylvania and some of them have significant water using communities within the basin. Projections of their water requirements and waste production are based on the projections of adjacent Projective Economic Study subareas.

New York State Counties

Population is projected by New York State economists on the basis of high and low county to Nation ratios and applied to high and low national projections to obtain subarea and county estimates. In Table 6b are shown the projected total populations for the three counties. The low projection indicates little increase by 2020 and the high projection indicates about a 25 percent increase in population from 1960 to 2020.

Agricultural output is projected to increase slightly from $48 million in 1960,to $60.6 million by 1980, and to $97.4 million by 2020.

The value of manufacturing output is projected to increase from seven to nine times its present value based on constant 1960 dollars.

Table 7b shows 1960 total employment and manufacturing employment. Manufacturing output projections as well as total employment and manufacturing employment projections for 1980, 2000, and 2020 are shown as indices using 1960 as the base.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

There are 210 central water supply systems in the Allegheny River Basin serving a population of over 1,713,000. The average daily municipal water use is over 215 mgd, amounting to 125 gallons per capita daily use.

In the basin, about 86 percent of the water used for municipal supplies is from surface sources. Although total water supplies from ground water sources is relatively small, amounting to about 32 mgd, there are about 137 central water supplies dependent on ground water sources. About 64 percent of the total water is used in Allegheny and Westmoreland Counties which are part of the Pittsburgh, Pennsylvania, S.M.S.A.

The present municipal and industrial water use in the basin is listed in Table 9 by county and totaled for economic subareas, with separate sublistings for the New York counties and other areas in the basin and totaled for the basin.

In the upper basin in Pennsylvania, generally outlined by the boundaries of minor area A-1, the major communities of Meadville, Bradford, Franklin, Oil City, and Warren account for over 70 percent of the water use. In the extreme upper reaches of the drainage area in New York State, the major communities of Jamestown, Olean, and Salamanca account for over 91 percent of the municipal water use in this area.

In the middle areas of the basin, generally defined by the boundaries of minor area A-2, the larger communities of Johnstown, Windber, Indiana, St. Marys, and Cresson, Pennsylvania, account for over 53 percent of the water use.

In other areas in the basin considered in this report but not included in Subarea A, are Dubois in Clearfield County, obtaining its water supply from Anderson Creek in the Susquehanna River Basin, and Latrobe in Westmoreland County.

Major industrial water use in minor area A-1 occurs in Crawford and Venango Counties, in minor area A-2 in Armstrong, Cambria, and Indiana Counties, and in other areas not included in Subarea A in Allegheny, Butler, and Westmoreland Counties.

Based on population increase and projected industrial activity, estimated water use is projected to increase in the Allegheny River Basin as shown in Table 10. It is estimated that total municipal and industrial water needs will increase nearly 2.75 times by 2020. The major increases will probably occur in or about the present centers of population and industrial activity mentioned previously.

Increases by 2020 by minor areas are A-1 less than 2 times, A-2 over 3.5 times, New York counties over 3 times, and other areas in the basin 2 times.

Based on increased production of agricultural commodities and a 64% increase of irrigated land (for the period 1954 to 1959), it is estimated that water needs for irrigation will increase 8 to 10 times by the year 2010.

Water Supply Problems

The projected total water supply figures shown in Table 10 and the 1 day in 30 year low flow data given in Table 5 and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11 are problem areas with the approximate time of onset.

In minor area A-1, the total average water use is projected to increase to 87 mgd by 1980, to 134 mgd by 2000, and to 199 mgd by 2020. Approximately 65 percent of the projected water use in this subarea will be for industrial use probably centered near the communities of Meadville on French Creek and Franklin and Oil City on the Allegheny River. Surface water Supplies in the Allegheny River appear to be adequate and ground water is available in the alluvium along French Creek and the Allegheny River in sufficient quantities to support these needs. Although municipal water needs by 1980 as projected will exceed the design capacity of present facilities at Titusville, the community should have sufficient water available in the alluvium to meet the projected needs.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Study.

TABLE 11

ALLEGHENY RIVER BASIN

Water Supply Problem Areas

Vicinity 1/	Minor Area	Present	1980	2000	2020
Titusville	A-1		X		
Bradford	A-1			X	
Kane	A-1			X	
Port Allegany	A-1			X	
Warren	A-1				X
Summer Hill Township	A-2		X		
Clarion	A-2			X	
Johnsonburg	A-2		X		
Blairsville	A-2	X			
Indiana	A-2		X		
Conemaugh Township	A-2		X		
Olean 2/	*			X	
Union City	*		X		

1/ Pennsylvania unless otherwise noted.
2/ New York State.
* Not included in Projective Economic Study but covered by economic study prepared by the State of New York.

In minor area A-2 by 1980, total water needs are projected to increase to 215 mgd, by 2000 to 330 mgd, and by 2020 to 520 mgd. About 75 percent of the projected water use is for industrial needs. Assuming that these needs will be located adjacent to or at points of present usage, major withdrawals will occur along the Allegheny River in Armstrong County in the Kittaning to Freeport reach, in Cambria County at Johnstown, in Elk County in the vicinity of Johnsonburg, and in Indiana County near Blairsville and Saltsburg. Since much of the water for industrial use in Armstrong County will probably be for cooling purposes and can be reused, adequate supplies to meet these projected needs can be obtained from the Allegheny River. Future needs at Johnsonburg, Saltsburg, and Blairsville will probably have to be met from surface sources. Blairsville and Saltsburg are located

along the Kiskiminetas and Conemaugh Rivers and surface flows in these streams are ample to supply future industrial needs. However, if the quality of these streams is not improved, they will not serve as sources of municipal supply and impoundments on tributary streams would be a better source. Johnsonburg is located on the Clarion River in the headwater region. Impounded storage will probably be required to meet needs in this area.

Indications are that the municipal water systems at Conemaugh Township and Summer Hill Township, both located on tributaries of the Conemaugh River, should be increasing their capacities by 1980.

Clarion, presently using ground water as a source of supply, should be planning to expand its source of supply after 1980. Indications are that expansion of its well field by tapping bedrock sources would probably be a logical solution although ample surface flow in the Clarion River appears to be available to meet projected needs.

Johnsonburg, located in the headwaters of the Clarion River, is now using ground and surface sources. It should be planning by 1980 to increase its production capacity. Indications are that ground water exists in sufficient quantity to meet future needs although impoundment of tributaries to augment present surface and ground sources could be a solution.

Blairsville presently along with Indiana by 1980 should be planning to increase their capacity. Both communities are presently using surface sources and additions to the present upland storage would probably be the solution to these problems although indications are that ground water exists in the bedrock in the Indiana County area which could be developed in conjunction with surface sources.

The community of Olean, New York, in the upper Allegheny River Basin should be planning for additional needs for supply by 2000. Olean, presently using a surface source, could augment this source from ground water supplies or increase their surface water supply by construction of upland reservoirs. Union City in Erie County, Pennsylvania, presently using surface sources, by 1980 will probably need additional raw water supplies. Ground water sources in the alluvium along French Creek could be a source of supply to meet these needs.

In the lower reaches of the Allegheny River and tributary streams in Allegheny and Westmoreland Counties, most of the industrial and municipal water supplies are obtained from the major streams where the quantity of water is ample to meet projected future needs.

Undoubtedly there are other smaller communities which will have water problems but it is beyond the scope of this report to define these problem areas.

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

Present untreated organic waste production is shown in Table 12. In the upper Allegheny River Basin not included in the Projective Economic Study, the major source of organic pollution is Olean, New York on the Allegheny River in Cattaraugus County. Jamestown, New York on Cassadaga Creek in Chautauqua County formerly a major source of organic pollution, has recently installed secondary treatment facilities which should decrease the organic load from this source.

In the upper portion of the basin in Pennsylvania, outlined generally by the boundaries of minor area A-1, major untreated organic waste products occur in Crawford and Venango Counties, accounting for nearly 60 percent of the total in minor area A-1. Major sources in Crawford County are at Meadville and Titusville and in Venango County at Oil City and Franklin.

In the middle portion of the basin, generally outlined by the minor area A-2 boundaries, major raw organic waste production results from the population in Cambria County. Over 50 percent of the total untreated domestic waste products in the area originate in the county with the major portion at Johnstown on the Conemaugh River.

In the lower portion of the basin, major untreated organic waste products are found in Allegheny and Westmoreland Counties, part of the Pittsburgh Standard Metropolitan Statistical Area (S.M.S.A.).

Most of the organic wastes in the greater Pittsburgh urban area in Allegheny County are collected and delivered for treatment to a plant operated by the Allegheny County Sanitary Authority located on the main stem of the Ohio River just below the confluence of the Allegheny and Monongahela Rivers. However, approximately 22 percent of the pollutional load in the entire Allegheny River Basin is located in Allegheny and Westmoreland Counties and is discharged to the Allegheny River, Kiskiminetas River, and tributary streams in the lower basin. The lower 72 miles of the Allegheny River are canalized and navigation dams have created a series of slack water pools. Flows (4,000 cfs, 90 percent frequency) from Allegheny Reservoir, now under construction by the Corps of Engineers, will appreciably improve conditions in these lower reaches of the Allegheny River.

Major industrial untreated organic waste products are found in Elk County, accounting for almost 50 percent of the total untreated organic waste products in minor area A-2. Most of this production of waste is located along the Clarion River in the Wilcox-Johnsonburg area.

Shown in Table 13 are the base and projected untreated organic waste production for the minor areas. Wastes tributary to the basin streams are projected to increase about 2.75 times by 2020, with wastes in minor area A-1 increasing about 3.25 times, in minor area A-2 about 3 times, in the New York counties about 3.5 times, and in other areas of the basin about 1.67 times.

Water Quality Control Problems

Listed in Table 14 are the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures for pollution control.

TABLE 14

ALLEGHENY RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity 1/	Economic Area	Approximate Beginning Date: Present	1980	2000	2020
Cassadaga Creek	Jamestown 2/	*	X			
Tunungwant Creek	Bradford	A-1	X			
French Creek	Meadville	A-1		X		
Paint Creek	Windber	A-2	X			
Two Lick Creek	Indiana	A-2			X	
Loyalhanna Creek	Latrobe	C	X			
Little Conemaugh Creek	Cresson	A-2	X			

1/ Pennsylvania unless otherwise noted.

2/ New York State.

* Not included in the Projective Economic Study but covered by economic study prepared by the State of New York.

The major quality control problem areas in the basin are in French Creek in the Clarion River, in the Kiskiminetas-Conemaugh Rivers system in Cassadaga Creek, and the Allegheny River below the confluence with the Kiskiminetas River.

In the upper portion of the basin, Jamestown, New York, discharges its wastes into Cassadaga Creek, a tributary of Conewango Creek. Cassadaga Creek has a design flow of approximately 10 to 15 cfs. At present, a flow of 25 cfs in the stream is needed to assimilate residual wastes remaining after secondary treatment. It is estimated that needs will increase to 40 cfs by 1980, 55 cfs by 2000, and 70 cfs by 2020. A treatment plant has been proposed to serve the township and communities adjacent to the southern end of Lake Chautauqua. Preliminary plans indicate the discharge will be to the Chadakoin River about 7 miles upstream from its confluence with Cassadaga Creek. It is anticipated that with 85% treatment and a population equivalent of 32,000 in 1970 this stream will also require low flow augmentation.

In minor area A-1 at Meadville in French Creek, if organic wastes are given secondary treatment, the design flow of 35 cfs is adequate at the present to assimilate residual wastes. However, by 1980 flows in the order of 40 cfs will be needed, increasing to 55 cfs by 2000, and 75 cfs by 2020. At Bradford on Tunungwant Creek where design flow is probably less than 10 cfs, total flow in the order of 25 cfs is needed at the present, increasing to 35 cfs by 1980, 50 cfs by 2000, and 65 cfs by 2020.

In minor area A-2 at Indiana, Pennsylvania, where a design flow of around 25 cfs occurs in Two Lick Creek, the need for a flow of 30 cfs is indicated by 2000, increasing to 40 cfs by 2020. Creason, located in the headwaters of Little Conemaugh Creek, is on a stream where the design flow would be expected to be very small. Flows in the order of 12 cfs are needed at the present, increasing to 17 cfs by 1980, 25 cfs by 2000, and 30 cfs by 2020. Windber, located on Paint Creek in the headwaters of the Conemaugh River where the design flow is very small requires a present flow in the order of 18 cfs even with secondary treatment. Continued increasing flows are anticipated to be needed in the future, in the order of 24 cfs by 1980, 32 cfs by 2000, and 43 cfs by 2020. Regulation of streamflow from storage is probably not the solution in these problem areas but rather intensive treatment and "polishing" or holding ponds where sewage plant effluent can be held and released during periods of higher flows.

In other areas at Latrobe located on Loyalhanna Creek, where design flow is about 15 cfs, flows in the order of 30 cfs are needed at the present, increasing to 35 cfs by 1980, 38 cfs by 2000, and 45 cfs by 2020.

Other water quality problems are heat, mine drainage, and chloride pollution. Major sources of heat release to the streams are from two thermal power generating plants located on the lower Allegheny River at Springdale and Colfax in Allegheny County and one plant located in Armstrong County. These plants have capacities of 416.1, 262.5 and 326.4 megawatts respectively. In the upper Allegheny River Basin there are plants located at Warren on the Allegheny River and at Jamestown, New York, on the Chadakoin River with generating capacities of 73.4 and 57.5 megawatts respectively. Two plants are located on the Conemaugh River, one at Seward with a capacity of 295.3 megawatts and one at Johnstown with a capacity of 74.5 megawatts. These plants use surface water for cooling purposes and, with the exception of the plants located along the Allegheny River, can cause high stream temperatures in localized stream reaches during periods of low flow.

Chloride pollution as the result of oil drilling operations is found in Oil Creek and mine drainage is a problem in the Kiskiminetas River, Clarion River, Redbank Creek, Cowanshannock Creek, and Crooked Creek drainage subbasins.

TABLES

TABLE 1

ALLEGHENY RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
New York		Allegany	17.4
Pennsylvania		Allegheny	31.4
"	*	Armstrong	100.0
"		Butler	29.1
"	*	Cambria	58.8
New York		Cattaraugus	74.2
"		Chautauqua	71.6
Pennsylvania	*	Clarion	100.0
"		Clearfield	9.9
"	*	Crawford	75.9
"	*	Elk	67.2
"		Erie	49.2
"	*	Forest	100.0
"	*	Indiana	91.9
"	*	Jefferson	100.0
"	*	McKean	97.4
"		Mercer	15.8
"		Potter	28.6
"	*	Somerset	37.7
"	*	Venango	97.8
"	*	Warren	100.0
"		Westmoreland	58.0

*Counties considered in Projective Economic Study of Allegheny River Basin.

TABLE 2

ALLEGHENY RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Allegheny River	11,730	325	0
Kiskiminetas River	1,892	27	30
Mahoning Creek	417	60	56
Red Bank Creek	586	75	65
Clarion River	1,232	110	86
French Creek	1,246	80	127
Oil Creek	340	45	134
Tionesta Creek	485	60	154
Conewango Creek	898	65	192

TABLE 3

ALLEGHENY RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Johnstown	Cambria	Pennsyl.	55,482	67,327	66,993	66,668	63,232	53,949
Jamestown	Chautauqua	New York	31,297	38,917	45,155	42,638	43,354	41,818
Wilkinsburg 1/	Allegheny	Pennsyl.	18,924	24,403	29,639	29,853	31,418	30,066
New Kensington 1/	Westmoreland	"	7,707	11,987	16,762	24,055	25,146	23,485
Olean	Cattaraugus	New York	14,743	20,506	21,790	21,506	22,884	21,868
Oil City	Venango	Pennsyl.	15,657	21,274	22,075	20,379	19,581	17,692
Meadville	Crawford	"	12,780	14,568	16,698	18,919	18,972	16,671
Bradford	McKean	"	14,544	15,525	19,306	17,691	17,354	15,061
Warren	Warren	"	11,080	14,272	14,863	14,891	14,849	14,505
Indiana	Indiana	"	5,749	7,043	9,569	10,050	11,743	13,005
Lower Burrell 1/	Westmoreland	"	-	-	-	-	-	11,952
Latrobe	"	"	8,777	9,484	10,644	11,111	11,811	11,932
DuBois	Clearfield	"	12,623	13,681	11,595	12,080	11,497	10,667
Plum 1/	Allegheny	"	-	-	-	-	-	10,241
Franklin	Venango	"	9,767	9,970	10,254	9,948	10,006	9,586
Arnold 1/	Westmoreland	"	1,818	6,120	10,575	10,898	10,263	9,437
Punxsutawney	Jefferson	"	9,058	10,311	9,266	9,482	8,969	8,805
Vandergrift	Westmoreland	"	3,876	9,531	11,479	10,725	9,524	8,742

1/ Part of Pittsburgh, Pennsylvania urbanized area. For Pittsburgh data see Section 13, Ohio River Main Stem, Appendix D.

TABLE 4

ALLEGHENY RIVER BASIN

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Mini. Pool Area (Acres)	Storage (acre-feet) Max.Flood Control	Water Supply	Maximum Summer
Lake Chautauqua*		13,400			
Tionesta Creek	F	480	125,600		7,800
East Branch Clarion River	F, A	90	38,700		65,300
Mahoning Creek	F	170	69,700		4,500
Crooked Creek	F	350	89,400		4,500
Conemaugh River	F	300	270,000		4,000
Loyalhanna Creek	F	210	93,300		2,000
Allegheny River	F, A	1,900	940,000		573,000
Piney Reservoir	P				28,900
Erie National Wildlife Refuge	R	100			
Lake Somerset	R	253			
Conneaut Lake	R				
Quemahoning Reservoir	R				

*Natural lake - capacity not determined.

F - Flood Control
P - Power
A - Low Flow Regulation
R - Recreation

TABLE 5

ALLEGHENY RIVER BASIN

Flow Data[1/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Allegheny River						
Eldred, Pennsylvania	550	966	22	55,000	26	15
Red House, New York	1,690	2,792	80	49,100	120	
Kinzua, Pennsylvania	2,179	3,830	149	60,500		
Franklin, Pennsylvania	5,982	10,320	334	138,000	470	301
Kittaning, Pennsylvania	8,973	15,710	570	269,000	778	529
Natrona, Pennsylvania	11,410	19,490	922	238,000	1,096	732
Kiskimenatas River						
Vandergrift, Pennsylvania	1,825	3,032	56	71,900	220	112
Conewango Creek						
Russell, Pennsylvania	816	1,470	58	14,400		
French Creek						
Utica, Pennsylvania	1,028	1,733	43	20,700		
Clarion River						
Cooksburg, Pennsylvania	807	1,448	41	32,700	55	
Conemaugh River						
Tunnelton, Pennsylvania	1,358	2,352	1	59,200	234	

1/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey."

TABLE 6a

ALLEGHENY RIVER BASIN

Economic Subarea A
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation A-1									
Pennsyl.	Crawford	78,000	25,000						
"	Forest	4,500	0						
"	McKean	54,500	23,200						
"	Venango	65,300	34,000						
"	Warren	45,600	14,500						
	Subtotal	247,900	96,700	322,450		391,340		463,000	
Area Designation A-2									
Pennsyl.	Armstrong	79,500	18,500						
"	Cambria	203,300	123,100						
"	Clarion	37,400	5,000						
"	Elk	37,300	19,400						
"	Indiana	75,400	17,900						
"	Jefferson	46,800	19,100						
"	Somerset	77,500	16,200						
	Subtotal	557,200	219,200	600,030		710,300		832,000	
Total Subarea A		805,100	315,900	922,480	430,000	1,101,640	587,000	1,295,000	805,000

TABLE 6b

ALLEGHENY RIVER BASIN

New York State Counties 1/
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
New York	Allegany	44,000	8,800						
"	Cattaraugus	80,200	32,600						
"	Chautauqua	145,400	82,700						
	LOW	269,600	124,100	281,100		281,600		271,000	
	HIGH	269,600	124,100	298,800		322,500		334,300	

1/ Ohio River Basin Economic Base Study - Subarea #20, Population and Employment Projections - 1970 to 2020 (preliminary). New York State Water Resources Commission and Department of Commerce - June 1965.

TABLE 7a

ALLEGHENY RIVER BASIN

Economic Subarea A
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation A-1													
Pennsyl.	Crawford	27,100	9,900										
"	Forest	1,500	600										
"	McKean	19,900	7,600										
"	Venango	20,900	8,100										
"	Warren	16,000	6,150										
	Subtotal	85,400	32,350	723.8	130	134	196	167	175	354	210	216	591
Area Designation A-2													
Pennsyl.	Armstrong	23,600	9,350										
"	Cambria	61,700	22,500										
"	Clarion	12,100	3,610										
"	Elk	12,500	6,600										
"	Indiana	23,000	5,200										
"	Jefferson	15,300	4,450										
"	Somerset	23,100	5,500										
	Subtotal	171,300	57,210	1277.0	120	122	179	151	154	313	185	206	542
Total Subarea A		256,700	89,560	2000.8	123	126	185	156	161	327	193	210	560

*In millions of 1960 dollars.
**1960 = 100

TABLE 7b

ALLEGHENY RIVER BASIN

New York State Counties 1/
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.** Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
New York	Allegany	14,700	3,900										
"	Cattaraugus	28,900	9,400										
"	Chautauqua	53,900	21,800										
	HIGH	97,500	35,100	100	115	104	212	133	109	449	154	114	952
	LOW	97,500	35,000	100	103	95	193	107	90	371	112	86	714

**1960 = 100

1/ Ohio River Basin Economic Base Study - Subarea #20, Population and Employment Projections - 1970 to 2020 (preliminary). New York State Water Resources Commission and Department of Commerce - June 1965.

TABLE 8

ALLEGHENY RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subareas	
New York	Allegany	*1/	
Pennsylvania	Allegheny	C	Pittsburgh SMSA
"	Butler	D	Beaver
New York	Cattaraugus	*1/	
" "	Chautauqua	*1/	
Pennsylvania	Clearfield	*	
"	Erie	*	
"	Mercer	D	Beaver
"	Potter	*	
"	Westmoreland	C	Pittsburgh SMSA

* - Not included in Projective Economic Study of Ohio River Basin.

* 1/- Not included in Projective Economic Study of Ohio River Basin, but covered in "Ohio River Basin Economic Base Study for Subarea 20" prepared by the Division of Water Resources, New York State Conservation Department.

TABLE 9

ALLEGHENY RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation A-1											
Pennsyl.	Crawford	9	33,290	30,660	2,630	5.445	5.068	.377	164	Wells, French Crk., Conneaut Lake	11.1
"	Forest	3	2,480	2,480		.150	.150		61	Wells, Springs	0.2
"	McKean	12	33,342	10,550	22,792	5.670	.923	4.747	170	Wells, Gilbert and Marrilla Runs	4.2
"	Venango	6	41,890	25,440	16,450	5.510	3.160	2.350	132	French Crk., Allegheny R., Wells	14.8
"	Warren	8	26,440	22,880	3,560	3.078	2.762	.316	116	Wells, Springs, Dear Lick Run, Tidoute Creek	1.8
	Subtotal	38	137,442	92,010	45,432	19.853	12.063	7.790	144		32.1
Area Designation A-2											
Pennsyl.	Armstrong	19	25,910	12,050	13,860	2.943	1.026	1.917	114	Allegheny R., Wells, Springs	41.6
"	Cambria	16	140,545	1,200	139,345	19.152	.085	19.067	136	Bear Rock Run, Bens Crk., S.Fk.L. Connemaugh, Mill Crk. Helsel and Trout Run, Wells	31.0
"	Clarion	11	13,615	11,665	1,950	1.180	.910	.270	87	Wells, Springs, Red Bank Crk.	0.3
"	Elk	9	22,610	2,110	20,500	3.379	.119	3.260	149	Wolf Lick, Laurel Run, Silver Crk., Big Mill Run, Lost Run, Power Run, Wells	11.6
"	Indiana	20	36,640	6,040	30,600	2.692	.342	2.350	74	Hillside Run, Two Lick Crk., Conemaugh R., Findley Run, Yellow Crk., Wells	20.7
"	Jefferson	8	23,653	1,630	22,023	2.421	.077	2.344	102	Whetstone and Rattlesnake Runs, N.Fk. Crk., Mahoning Crk., Wells	0
"	Somerset	16	35,301	4,520	30,791	3.525	.328	3.197	100	Bens Crk., Clear Shade Crk., Wells	0
	Subtotal	99	298,274	39,215	259,059	35.292	2.887	32.405	118		105.2

TABLE 9 (cont'd)

ALLEGHENY RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
New York State Counties in Basin											
New York	Allegany	4	4,075	4,075		.294	.294		72	Wells, Springs	0.5
"	Cattaraugus	12	49,255	14,755	34,500	7.030	1.730	5.300	143	Olean Crk., Newton Run. Wells, Springs	4.3
"	Chautauqua	9	62,495	62,495		7.340	7.340		118	Wells, Springs	0.1
	Subtotal	25	115,825	81,325	34,500	14.664	9.364	5.300	127		4.9
Other Areas in Basin											
Pennsyl.	Allegheny	20	1,027,755	52,155	975,600	127.986	5.436	122.550	125	Allegheny River, Wells	100.0
"	Butler	2	1,490	1,490		.087	0.087		58	Well, Springs	16.1
"	Clearfield	2	15,210	210	15,000	2.014	.014	2.000	132	Anderson Creek, Wells	0
"	Erie	5	16,150	12,350	3,800	1.862	1.412	.450	115	Bentley Run, Wells	.3
"	Mercer	2	2,065	2,065		.120	.120		58	Well, Springs	0
"	Potter	3	3,200	3,200		.632	.632		198	Lanagar Run, Spring, Wells	0.9
"	Westmoreland	14	95,750	1,500	94,250	12.972	.070	12.902	136	Allegheny R., Tubmill Crk., Trout Run, Loyalhanna Creek, McGee Run, Wells, Bear Pond Run	18.2
	Subtotal	48	1,161,620	72,970	1,088,650	145.673	7.771	137.902	125		135.5
	TOTAL	210	1,713,161	285,520	1,427,641	215.482	32.085	183.397	125		277.7

TABLE 10

ALLEGHENY RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation A-1												
From Central Supplies	137,442	144	19.8	210,300	160	33.6	294,000	165	48.5	407,000	170	69.0
Industrial			32.1			53.4			85.5			130.0
Subtotal			51.9			87.0			134.0			199.0
Area Designation A-2												
From Central Supplies	298,274	118	35.3	381,800	129	49.3	514,000	140	72.0	704,000	156	110.0
Industrial			105.2			158.0			246.0			394.0
Subtotal			140.5			207.3			318.0			504.0
New York Counties in Basin												
From Central Supplies	115,825	127	14.7	150,000	140	21.0	183,000	153	28.0	217,000	161	35.0
Industrial			4.9			8.0			14.0			26.0
Subtotal			19.6			29.0			42.0			61.0
Other Areas in Basin												
From Central Supplies	1,161,620	125	145.7	1,277,800	137	175.0	1,487,000	140	208.0	1,777,000	152	270.0
Industrial			135.5			161.0			210.0			295.0
Subtotal			281.2			336.0			418.0			565.0
Allegheny River Basin												
From Central Supplies Total	1,713,161	125	215.5	2,019,900	136	278.9	2,478,000	143	356.5	3,254,000	154	500.0
Industrial Total			277.7			380.4			555.5			845.0
GRAND TOTAL			493.2			659.3			912.0			1345.0

TABLE 12

ALLEGHENY RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation A-1						
Pennsyl.	Crawford	5	41,650	French Crk., Oil Crk., Conneaut Lake	41,650	15,900
"	Forest	2	1,415	Allegheny R., Millstone Creek	1,415	1,000
"	McKean	8	27,205	Tunungwant Creek, Herbert Run, Allegheny River	27,205	12,000
"	Venango	6	40,775	Allegheny River, Oil Creek	40,775	9,400
"	Warren	5	19,260	Allegheny R., Brokenstraw Crk., Tionesta Creek	19,260	10,300
	Subtotal	26	130,305		130,305	48,600
Area Designation A-2						
Pennsyl.	Armstrong	12	26,090	Allegheny R.,Kiskiminetas R.	26,090	16,800
"	Cambria	17	151,075	Conemaugh R.,Stony Crk.,L.Conemaugh R.	151,075	60,500
"	Clarion	9	41,795	Red Bank Creek	41,795	10,600
"	Elk	3	21,300	Clarion R., Elk Creek	21,300	95,500
"	Indiana	6	21,830	Twolick Crk.,Conemaugh R.	21,830	14,900
"	Jefferson	5	19,965	Mahoning Crk., Red Bank Crk., Sandlick Crk.,Kiskiminetas R.,L.Toby Crk.	19,965	7,100
"	Somerset	9	17,080	Paint Creek	17,080	6,200
	Subtotal	61	299,135		299,135	211,600

TABLE 12 (cont'd)

ALLEGHENY RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*: Domestic & Commercial	Raw Waste Production Before Treatment Population Equivalent*: Estimated Industrial
New York State Counties						
New York	Allegany	3	3,435	Oil Crk., L.Gennessee Crk.	3,435	2,000
"	Cattaragus	8	37,865	Allegheny R., Ischua and Dodge Crks.	37,865	22,400
"	Chautauqua	6	57,365	Cassadaga Crk., Chadakoin R., Little Chautauqua River	57,365	53,200
	Subtotal	17	98,665		98,665	77,600
Other Counties in Basin						
Pennsyl.	Allegheny	30	116,280	Allegheny R., Pine Crk., Willow Run, Chalfont Run, W.Br.Deer Creek	116,280	49,300
"	Clearfield	2	13,500	Sandy Lick Creek	13,500	3,500
"	Erie	4	15,210	Brokenstraw Crk., French Crk., Conneaut Creek	15,210	4,400
"	Potter	2	3,400	Allegheny R., Oswayo Creek	3,400	3,600
"	Westmoreland	14	87,600	Allegheny R., Loyalhanna Creek, Kiskiminetas R., McGee Run	87,600	8,000
	Subtotal	52	235,990		235,990	68,800
	TOTAL	156	764,095		764,095	406,600

*NOT to be interpreted as waste loads to the stream.

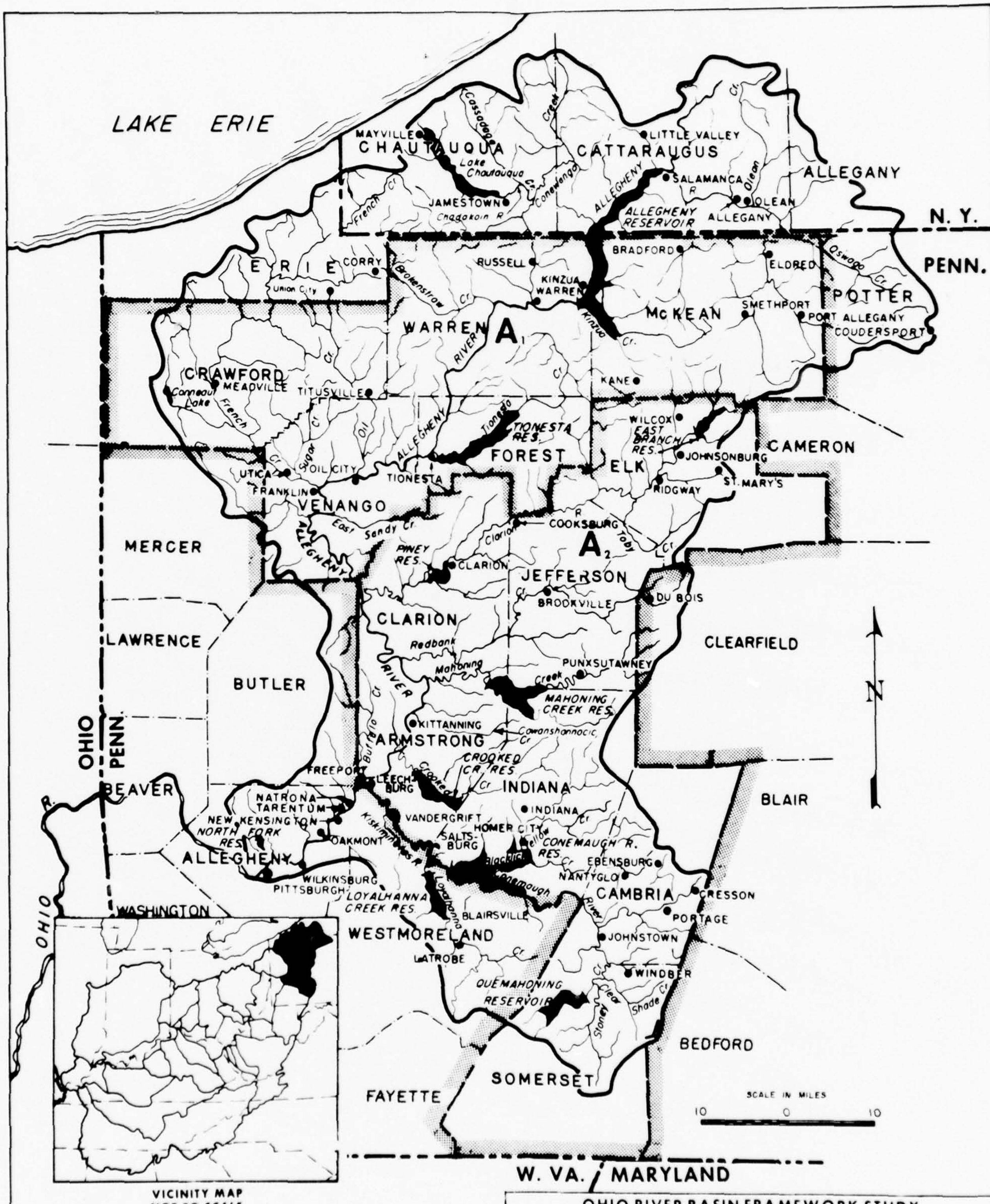
TABLE 13

ALLEGHENY RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation A-1				
Domestic and Commercial	130,305	199,400	278,900	386,000
Industrial	48,600	80,200	128,800	196,000
Subtotal	178,905	279,600	407,700	582,000
Area Designation A-2				
Domestic and Commercial	299,135	382,900	514,500	706,000
Industrial	211,600	317,400	495,100	791,000
Subtotal	510,735	700,300	1,009,600	1,497,000
New York State Counties				
Domestic and Commercial	98,665	151,000	211,100	292,000
Industrial	77,600	128,000	205,600	313,000
Subtotal	176,265	279,000	416,700	605,000
Other Counties in Basin				
Domestic and Commercial	235,990	257,200	297,300	352,000
Industrial	68,800	81,200	104,600	146,000
Subtotal	304,790	338,400	401,900	498,000
Allegheny River Basin				
Domestic and Commercial Total	764,095	990,500	1,301,800	1,736,000
Industrial Total	406,600	606,800	934,100	1,446,000
GRAND TOTAL	1,170,695	1,579,300	2,235,900	3,182,000

*NOT to be interpreted as waste loads to the stream.



RIVER BASIN BOUNDARY

PROJECTIVE ECONOMIC STUDY BOUNDARY

COUNTY LINES

STATE LINES

OHIO RIVER BASIN FRAMEWORK STUDY

ALLEGHENY RIVER BASIN
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 1-1

MONONGAHELA RIVER BASIN

Subbasin Area
No. 2

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I SUMMARY

Municipal and Industrial Water Supply Problems

Additional quantities of water are, or will be needed to supply four communities in the basin. The communities of Weston and Bridgeport, West Virginia, both have an immediate need for additional water, and the communities of Clarksburg and Elkins are projected to have a need for additional water by the year 1980.

Industrial activity within the basin is largely concentrated in the Pittsburgh metropolitan area in the lower reaches of the Monongahela River. Steel making is the chief industry and vast quantities of cooling water are used in its production. There is an adequate quantity for these uses although the water quality is quite poor in the lower portions of the river due to mine drainage.

Water Quality Control Problems

The major water quality control problem within the Monongahela River Basin is that of acid mine drainage. The Monongahela River is acid throughout its length, and the West Fork, Tygart Valley, Cheat, and Youghiogheny Rivers are acid for more than half of the length of their main stems.

Charleroi, Pennsylvania, on the main stem of the Monongahela River was selected as a dividing point, since acid contributions above this point are mainly from acid mine discharges. Below this point, industries within the Pittsburgh metropolitan complex contribute both acidity and alkalinity to the stream.

By providing treatment of the acid wastes originating from active mining operations within the basin, together with an extensive program of applying known remedial measures at the source of acid mine drainage originating from abandoned mines, acid loads in the main stem of the Monongahela River and major tributaries can probably be reduced in the order of 50 to 70 percent of present values. The reduction, if realized, will still be insufficient to bring the water quality of the main stem to an acceptable minimum pH level of 6, and streamflow regulation might be an interim solution pending continued extension of control of mine drainage.

The major water quality problem due to residuals remaining after secondary treatment of organic wastes is located in the Pittsburgh area. A need exists in the area for low streamflow regulation during the critical season in the order of 2,100 cfs at the present, 2,700 cfs by 1980, 3,575 cfs by 2000, and 4,450 cfs by the year 2020. The present 7-day average once in ten year low flow at Braddock, Pennsylvania, is 1,820 cfs.

If the acid concentrations in the streams were reduced to a point where aquatic life could again exist, then problems would develop during low flow periods from the discharge of residual organic wastes remaining after secondary treatment. The major problem areas would be in the West Fork River below Clarksburg, in Redstone Creek below Uniontown, Pennsylvania, in Jacks Run below Greensburg, Pennsylvania, and in Brush Creek below Jeannette, Pennsylvania.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Monongahela River Basin includes approximately 7,380 square miles in northern West Virginia, southwestern Pennsylvania, and northwestern Maryland. The portion of the basin in West Virginia consists of 4,150 square miles and the portion of the basin in Pennsylvania and Maryland consists of approximately 2,730 and 500 square miles, respectively. The basin is bounded on the west by main stem Ohio River drainage, on the south by the Little Kanawha and Kanawha River Basins, on the east by the Potomac River Basin, and on the north by the Allegheny River Basin. It is located in all or part of 11 counties in West Virginia, six counties in Pennsylvania, and one county in Maryland, as shown in Table 1.

The Monongahela River is formed by the confluence of the West Fork and Tygart Valley Rivers at Fairmont, West Virginia. The river flows in a northerly direction for 129 miles and joins the Allegheny River at Pittsburgh to form the Ohio River. Pertinent data regarding the major tributaries are shown in Table 2. The basin is shown on Figure 2-1, page 2-32.

Physical Features

The Monongahela River Basin is located in the Appalachian Plateaus physiographic province, mostly in the Kanawha section and partly in the Allegheny Mountains section. This area represents a mature plateau of fine texture with moderate to strong relief. Erosion has reduced almost all the land area to slope. The terrain is rugged and the valleys are deep and narrow. Flat areas are limited to narrow flood plains and some terraces and flat-topped hills. The elevations of the basin range from a high of approximately 4,600 feet above sea level in the headwaters of the Cheat River to about 700 feet above sea level at Pittsburgh, giving a maximum relief of nearly 4,000 feet.

Physiographic features and geology of the Monongahela Basin are described in detail in the U. S. Geological Survey Groundwater Report.1/

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

Unconsolidated alluvium of clay, silt, sand, and gravel of Pleistocene and Recent ages is present along the major stream valleys. The deposits are usually coarser toward the base. Remnants of ancient lake terrace alluvium are present on hill areas about two hundred feet higher than the Monongahela River.

The prevalence of slopes and rugged terrain severely restrict the acreage suitable to cultivation. Except in localized areas, erosion is not now severe; but considerable erosion occurred formerly due to lumbering, unsound farm practices, and mining activities. Currently erosion is greatest in the western third of the basin due either to one of several factors or to a combination of them; namely unprotected strip mined areas, highly erosive shale soils, cultivated or overgrazed slopes, and unprotected soil in urban developments, particularly in the Pittsburgh area. Most of the basin, however, either is forested or under a protective grass cover.

Climate

The Monongahela River Basin is characterized by a continental climate. Seasons are of near equal length. Winters are moderate to severe, but summers are mild to warm. Topographic differences in the basin cause marked variations in precipitation and temperature between the mountainous areas and the hilly plateau lands. The area geographically is in a region of frontal air mass activity, being subjected alternately to polar and tropical air masses. Frequent and rapid changes in weather occur due to the passage of fronts associated with general low pressure areas.

The mean annual temperature ranges from about 48°F at high elevations to about 56°F at lower elevations. Average monthly temperatures are highest in July and lowest in January with an approximate range of from 74°F to 34°F. Precipitation is ample and well distributed through the seasons with an average annual amount of nearly 50 inches, and varying from about 42 inches at low elevations to approximately 54 inches at high elevations. Snow covers the ground much of the time during winter. The growing season has an average length of about 130 days at high altitudes to approximately 150 days in the western part of the basin.

Principal Communities and Industries

Most of the agriculture, manufacturing, mining, and urban and industrial centers are located in the western half of the basin with much of the basic steel industry in the basin located in the lower reach of the Monongahela River. Forested lands are more concentrated in the eastern half. Hay and livestock are the chief agricultural products. Much coal mining has occurred in the basin, and coal extraction continues to be important in the western third of the basin in the general vicinity of the West Fork River, the main stem of the Monongahela River, and in portions of Preston County, West Virginia and Somerset County, Pennsylvania. Industries are concentrated along the West Fork River and main stem Monongahela River.

Most of the principal communities in the basin are a part of the Pittsburgh urban area. Other larger communities are Clarksburg, Morgantown and Fairmont, West Virginia. The 1910 to 1960 populations of the principal communities in the basin are shown in Table 3.

III WATER RESOURCES

Surface Water Resources

Quantity

Streamflow in the basin is regulated to some extent by multiple-purpose dams and headwater reservoirs.

Shown in Table 4 are pertinent data regarding impoundments in the basin.

The four existing reservoirs operated by the U. S. Army Corps of Engineers, Tygart, Youghiogheny, Lake Lynn, and Deep Creek, have a total storage of 429,000 acre-feet for flood protection and 590,970 acre-feet for other purposes, such as hydroelectric power, navigation and recreation. Lake Lynn and Deep Creek Reservoirs are operated for the purpose of producing hydroelectric power and have a combined storage capacity of 341,770 acre-feet.

Storage in the Tygart Reservoir is released to maintain a minimum flow of 340 cfs at Lock and Dam No. 8 on the Monongahela River.

The Rowlesburg and Stonewall Jackson Reservoirs under study by the Corps of Engineers would provide an additional 337,600 acre-feet of storage for flood control and 617,700 acre-feet for regulation of streamflow for purpose of water quality control, hydroelectric power, and as a source of water for municipal use.

Of the basin's entire 7,380 square mile drainage area, the present Tygart, Youghiogheny, and Lake Lynn Reservoirs control a total of 3,031 square miles. The proposed Stonewall Jackson Reservoir would increase this amount by another 102 square miles.

The main stem Monongahela River is navigable throughout its 129 mile length from its mouth to its confluence with the Tygart and West Fork Rivers.

Shown in Table 5 are streamflow data for the Monongahela River excerpted from hydrology data[1] prepared by the Corps of Engineers.

Quality

Surface waters in the basin are generally of very poor quality. This is largely due to pollution by mine drainage. Of the twenty major subbasins within the Ohio River Basin, the Monongahela River Basin is by far the most seriously polluted with respect to mine drainage. The main stem of the Monongahela River is acidic in nature throughout the entire year. In addition, mine drainage is a major stream pollutant in every significant watershed which is tributary to the main stem of the Monongahela River.

Generally speaking, the alkaline surface water within the basin is restricted to small tributaries located in the western, southern, and southeastern extremities of the Monongahela River Basin. It is also significant to note that on the main stem of the Monongahela River between Fairmont, West Virginia, and Pittsburgh, Pennsylvania, the bulk of the residual acidity carried by the river is contributed by numerous small tributaries within this stream reach. Of further significance is the fact that roughly a 10 percent depletion of the coal reserves of the States of Pennsylvania and West Virginia has created the vast problem of acid mine drainage pollution. Unless adequate control measures are developed and applied, the exploitation of the remaining coal reserves could result in an even greater water pollution problem.

Although pollution from acid mine drainage is the major problem within the basin, organic waste loads from industries and municipalities are also significant. The impact of these organic wastes, however, on the various receiving streams is often masked by the presence of large amounts of acidity.

Ground Water Resources

Quantity

Ground water resources are described by the U. S. Geological Survey[2] and the following discussion has been condensed from this information.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The basin is underlain by (Paleozoic) sedimentary rocks composed of alternating layers of sandstone, shale, coal, and some limestone. Alluvium is present in all the major stream valleys and is a source of significant amounts of water along the major drainage in the lower part of the basin. The Monongahela Basin is entirely unglaciated.

The chief sources of ground water in the basin are the coarse-grained sandstones and conglomerates of the Pottsville and Allegheny formations. The sandstones of the Pottsville formation are poorly cemented and fractured and, therefore, are the best aquifers in the basin. These formations are available at the surface in wide parallel bands trending north-south in the central and eastern parts of the basin. Throughout these areas, the Pottsville aquifers will generally yield more than 100 gallons per minute (gpm) to wells, and reportedly yield more than 300 gpm to some wells. In some areas, the Pottsville and Allegheny formations are virtually untested for yield.

River alluvium along the lower reaches of the Monongahela and Youghiogheny Rivers contains appreciable thicknesses of poorly sorted sand and gravel. The largest well yields from the basin's alluvial deposits are obtained from these sand and gravel deposits. Yields of 300 gpm can be obtained from the river alluvium along the Monongahela River below Brownsville, Pennsylvania, and along the Youghiogheny River below West Newton, Pennsylvania. Large yields from these deposits have been sustained by induced infiltration of the overlying river water.

Quality

Ground water from all the chief sources in the basin generally contains iron in objectionable concentrations. With the exception of iron content, the water from the sandstone aquifers is of good quality.

Water from the alluvium of the lower Monongahela and Youghiogheny Rivers is of variable quality partly due to contamination by polluted river water and by recharge infiltrating through blast-furnace slag piles.

The total dissolved solids content of water from the alluvium generally ranges from 300 to 3,000 mg/l, and the hardness generally ranges from 120 to 1,700 mg/l. The higher values most likely are due to the presence of acid stream water that entered the aquifer by induced infiltration due to pumping.

Water from the principal bedrock aquifers is softer with hardness concentrations generally ranging from 10 to 350 mg/l. The total dissolved solids generally range from 50 to 600 mg/l.

IV THE ECONOMY

The Monongahela subarea contains the middle and upper portions of the drainage basin of the Monongahela River. The subarea includes two counties in Pennsylvania, the extreme western county of Maryland, and ten counties in West Virginia. The area is divided into two minor areas, B-1 and B-2, to facilitate future estimates of water requirements and waste loads. The B-1 minor area includes the seven western counties, and B-2 includes the remaining six eastern counties in the middle and upper portion of the basin. The counties in each minor area are listed in Tables 6 and 7 and shown in Figure 2-1, page 2-32. The entire subarea is within the region designated as Appalachia.

Economic Profiles

Minor Area B-1

Population in this minor area was 440,600 in 1960, with five cities having populations between 12,000 and 28,000. These cities are Clarksburg, 28,100, Morgantown, 22,500, and Fairmont, 27,500, all in West Virginia, and Uniontown and Connellsville, Pennsylvania, 18,000 and 12,800 respectively. Average personal per capita income amounted to $1,396 in the area compared to $1,378 for West Virginia, $1,855 for Pennsylvania, and $1,850 for the Nation.

Manufacturing is the most important employment category. Manufacturing employment has manifested a low growth rate of 0.3 percent per annum from 1950 to 1960. The most important industries are other durables, primary metals, machinery (including electrical machinery), and food processing. Two thermal power generating plants are located in the area with a total generating capacity of 229 megawatts.

Coal mining is a major industry in this area. In 1960, 35 million tons of coal were produced equaling 29.6 percent of West Virginia's total production. Although 17,800 people were employed in mining in 1960, this was less than half the 1950 figure, and coal production is expected to manifest a continuing growth in output. Oil and gas production are next in importance, but no production

figures are available on the county basis. However, 24 new producing oil wells, 100 new gas wells, and 33 new combination gas and oil wells were drilled in the West Virginia counties in 1963. In West Virginia as a whole, 97, 641, and 219 such wells respectively were completed in 1963.

The total value of farm products sold increased $3.5 million over 1954 to $16.3 million by 1959. Dairy products accounted for 42 percent of the total value in Fayette and Greene Counties, Pennsylvania and 35 percent for the area as a whole. Three hundred acres were irrigated in 1959.

Minor Area B-2

Minor area B-2 is sparsely settled with a population of 115,500 in 1960 and an average personal per capita income well below that of West Virginia--$1,022, compared to $1,378 for the State. Urban population accounted for only 15 percent of total population in comparison to 38 percent for the State of West Virginia.

Although manufacturing is the most important employment category, it is still in a developing stage. In 1964, there were only 13 plants with over 100 employees, and 11 of these were in the 100-249 employee category. The most important industries are furniture and wood products, apparel, food processing, and fabricated metals. Three thermal power generating plants are located in the area with a total capacity of 271.5 megawatts.

Mining is the second most important commodity employment category and is centered around fossil fuel production. Nine and three-tenths million tons of coal were produced in 1960 representing 7.9 percent of the State of West Virginia total production. Although county figures on the production of gas and oil are not available, 35 producing oil wells and 73 producing gas wells were drilled in 1960 in the West Virginia portion of the minor area.

Agriculture has followed historical trends. Employment in 1960 was less than half the 1950 figure, but the value of agricultural output increased four million dollars from the 1954 figure to a total of $14.9 million in 1959. Livestock and livestock products accounted for 35 percent of this total, dairy products amounting to 29 percent. A total of 1,200 acres were irrigated in 1959.

Projected Population and Industrial Activity

Population of the Monongahela subarea is projected to increase from 556,100 in 1960 to 750,000 by 2020. The 1960 area population represented 2.9 percent of Ohio River Basin population, but it is projected to represent only 2.2 percent by the year 2020. Shown in Table 6 is the 1960 and projected population for minor areas B-1 and B-2.

Agricultural output is expected to decline from $87.1 million in 1960 to $80.3 million in 1980 and then increase to about $91.7 million by 2010.

Manufacturing output is expected to show a steady increase from $675 million in 1960 to about $3 billion by the year 2010.

Shown in Table 7 is total employment, manufacturing employment and manufacturing output for 1960. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Monongahela subarea in the Projective Economic Study, five other counties have land area within the Monongahela River Basin. These counties are listed in Table 8. In some of the counties there are communities with significant water use and organic waste loads and projections of their water requirements and waste loads are based on the projections of the Projective Economic Study subarea in which they are located.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

There are 118 central water supplies in the Monongahela River Basin serving a population of 1,324,000. The average daily water use is 142 mgd, amounting to 107 gallons per capita daily use.

In the basin, 97 percent of the water used for municipal supplies is from surface sources. Municipalities in Allegheny County account for 53 percent of the water from surface sources as well as about 53 percent of the total municipal water use in the basin.

The present municipal and industrial water use in the basin is listed in Table 9 by county. Subtotals are listed for each economic subareas and other areas in the basin. In the designation listed as "Other Areas in the Basin," the county of Allegheny, Pennsylvania, accounts for about 65 percent of the population served by central systems and approximately 71 percent of the water use.

The major industrial water use is for the steel, chemical and allied product industries located in Allegheny County which is part of the Pittsburgh S.M.S.A. This use accounts for about 98 percent of the total industrial water use within the Monongahela River Basin. This large industrial use is 53 percent of total industrial water use in the Ohio River Basin under study. The importance of industrial water supply to the area is thus illustrated.

Based on population increase and projected industrial activity, estimated water use will increase in the Monongahela River Basin as shown in Table 10. It is estimated that total municipal and industrial water requirements will increase over twofold by the year 2020. The major increases will probably occur in or about the present centers of population and industrial activity.

Water Supply Problems

The projected total water supply figures shown in Table 10, the 1 day in 30 years low flow data given in Table 5, and availability

of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Problem areas with approximate time of onset are shown in Table 11.

TABLE 11

MONONGAHELA RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Bridgeport, W.Va.	B-1	X			
Elkins, W.Va.	B-2		X		
Weston, W.Va.	B-1	X			
Clarksburg, W.Va.	B-1		X		

In minor area B-1, the total water use is projected to increase to 71.5 mgd by 1980, to 116 mgd by 2000, and to 158 mgd by 2020. About 60 percent of the projected water use in this subarea will be for industrial use. It is anticipated that increased industrial activity will occur in the areas of Clarksburg in Harrison County, West Virginia, and Weston in Lewis County, West Virginia, if the Stonewall Jackson Reservoir on the West Fork River becomes a reality.

Therefore, the cities of Clarksburg and Weston are expected to continue to show an increasing demand for water. The present water use for Clarksburg is 5.3 mgd, and this is expected to increase to about 18.6 mgd by the year 2020. There will be a need for about 2 mgd additional water to serve this community by the year 1980, increasing to about 13 mgd additional water supply by 2020. The city of Weston's present water use is 1.1 mgd. However, their water supply is presently inadequate during periods of drought since low flows approach zero, and there is an immediate need for additional water to serve this community. Therefore, storage to provide a flow of about 1.1 mgd is needed now, increasing to about 4.5 mgd by the year 2020.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The municipal water use in the community of Bridgeport in Harrison County, West Virginia, is primarily for residential use. This community draws its supply from two small presently inadequate impoundments on Davisson Run. Assuming that industrial expansion will occur in the Clarksburg, West Virginia area, an increase in population will probably occur in Bridgeport. The need for supply can probably be met from additional impoundments in this area.

In minor area B-2, the total water use is projected to increase to 5 mgd by 1980, 7 mgd by 2000, and 10.5 mgd by 2020. About 30 percent of the projected water use in this subarea will be for industrial use. It is assumed that Elkins in Randolph County, West Virginia, the largest community in this minor area, will be the hub of increased water use. This community draws its supply from the headwater reaches of the Tygarts Valley River. The supply of water from these upstream sources will be inadequate by 1980 and local impoundments for storage of water for supply or groundwater can probably meet future needs.

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

Present organic waste loads generated in the Monongahela River Basin are shown in Table 12. The portion of the Pittsburgh, Pennsylvania, industrial complex located in the Monongahela River Basin includes portions of Allegheny, Westmoreland, Washington, Greene, and Fayette Counties in Pennsylvania. These five counties account for about 75 percent of the total domestic and commercial organic pollutional load generated in the basin. This area also contributes about 83 percent of the total estimated industrial organic pollution load generated in the Monongahela River Basin. In the entire basin, industry contributes about 27 percent of the total organic waste load generated.

Shown in Table 13 are the base and projected waste loads generated for the various minor areas. Waste loads generated are projected to increase on an average of 1.15 times by the year 1980, 1.5 times by 2000, and 2 times by 2020.

Water Quality Control Problems

As previously indicated, the present major water quality control problem within the Monongahela River Basin is that of mine drainage.

The Monongahela River is acid throughout its length and the major tributaries, the West Fork, Tygart Valley, Cheat and Youghiogheny Rivers are acid for more than half of the length of their main stems.

Some of the effects of mine drainage in the receiving stream and its subsequent use are well known. Waters which contain quantities of mine drainage have a deleterious effect upon fish and related aquatic life, which usually results in the elimination of practically all stream life. The esthetic value of the stream is normally ruined with a corresponding decline in adjacent property values. High concentrations of minerals commonly contained in mine waters make the use of the receiving stream either unsuitable for other industrial and municipal purposes, or requires special water treatment at additional cost. The corrosive nature of acid waters is particularly objectionable due to the extensive use of the Monongahela River for navigation, as well as a source of municipal and industrial water supply.

The water quality of the Monongahela River Basin, therefore, must be classified as generally degraded, with the major pollutant being mine drainage.

The largest organic contributions occur in the lower portion of the main stem of the Monongahela River within the industrial complex of metropolitan Pittsburgh. In this area, steel is the chief product. A very large volume of cooling water which is extracted from the Monongahela River is treated with lime, etc., to reduce its corrosive properties prior to utilization by the steel industry in this area. Due to this, as well as to recent technological changes in the steel pickling operation, the lower portions of the river appear to have been buffered to some degree.

Although the effects of the organic loads from municipalities and industries within the basin are presently often masked by the existing acid problem, it is anticipated that if the acid problem can be greatly brought under control the impact of the organic wastes would be noticed. In the absence of large concentrations of acids, calculations indicate that the residual organic waste loads after the application of secondary treatment or equivalent reduction measures would result in water quality problems in the Pittsburgh area and in the areas of fourteen other communities within the basin. These communities and the tributary affected are shown in Table 14.

It is interesting to note that all the areas which would be expected to have a water quality problem within the study period, as a result of residual organic wastes, would actually be anticipated to have an immediate problem if the acid problem did not exist in the streams.

The major organic contributions within the basin are to the main stem of the Monongahela River in the Pittsburgh metropolitan area. Although the majority of the municipal and some industrial waste loads during dry weather conditions are treated and discharged into the Ohio River via the Allegheny County Sanitary Authority System, there are several communities and a large number of industries which discharge organic loads to the Monongahela River. In addition, the Pittsburgh area has a large number of combined sewers which discharge to the Monongahela River during wet weather. Past studies indicate that even after secondary treatment, the residual organic loads to the Monongahela River in the Pittsburgh area would be such that additional streamflow regulation for quality control is needed.

TABLE 14

MONONGAHELA RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Monongahela River	Pittsburgh,Pa.	C	X			
West Fork River	Clarksburg,W.Va.	B-1	X			
West Fork River	Weston, W.Va.	B-1	X			
Redstone Creek	Uniontown, Pa.	B-1	X			
Beards Run	Bridgeport,W.Va.	B-1	X			
Buffalo Creek	Mannington,W.Va.	B-1	X			
S.Fork Ten Mile Creek	Waynesburg, Pa.	B-1	X			
Tygart Valley R.	Elkins, W.Va.	B-2	X			
Buckhannon River	Buckhannon,W.Va.	B-2	X			
Jacks Run	Greensburg, Pa.	C	X			
Brush Creek	Jeannette, Pa.	C	X			
Brush Creek	Irwin, Pa.	C	X			
Jacobs Creek	Scottdale, Pa.	C	X			
Coxes Creek	Somerset, Pa.	A-2	X			
Pigeon Creek	Bentleyville,Pa.	C	X			

These studies show a need in the Monongahela River in the Pittsburgh area for a minimum summer streamflow in the order of 2,100 cfs, 2,700 cfs by 1980, 3,575 cfs by 2000, and 4,450 cfs by the year 2020. The present 7-day average once in ten year low flow (called the design flow) at Braddock, Pennsylvania, is 1,820 cfs.

In Jacks Run at Greensburg, Pennsylvania, the design flow is less than 1 cfs. Summer flows in the order of 30 cfs would be required at the present, increasing to 35 cfs in 1980, 40 cfs in 2000, and 50 cfs in the year 2020.

In the West Fork River below Clarksburg, West Virginia, the design flow is about 2 cfs. Summer flows in the order of 25 cfs are required at the present, increasing to 30 cfs in 1980, 40 cfs in 2000, and 50 cfs by the year 2020.

At Jeannette, Pennsylvania, the design flow of Brush Creek is less than 1 cfs. Summer flows in the order of 15 cfs are required at the present, increasing to 25 cfs by the year 2020.

In the Redstone Creek at Uniontown, Pennsylvania, the design flow is less than 1 cfs. Summer flows in the order of 10 cfs are required at the present, increasing to 20 cfs by the year 2020.

Other points of streamflow needs shown in Table 14 are presently less than 5 cfs, increasing to about 10 cfs, or less, by the year 2020 depending upon the area involved.

TABLES

TABLE 1

MONONGAHELA RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Pennsylvania		Allegheny	30.7
West Virginia	*	Barbour	100.0
Pennsylvania	*	Fayette	100.0
Maryland	*	Garrett	63.8
Pennsylvania	*	Greene	78.7
West Virginia	*	Harrison	100.0
" "	*	Lewis	62.5
" "	*	Marion	100.0
" "	*	Monongalia	100.0
" "		Pocahontas	3.6
" "	*	Preston	99.0
" "	*	Randolph	91.3
Pennsylvania		Somerset	48.8
West Virginia	*	Taylor	100.0
" "	*	Tucker	100.0
" "	*	Upshur	83.0
Pennsylvania		Washington	36.8
"		Westmoreland	42.0

*Counties considered in economic projections of Monongahela River Basin.

TABLE 2

MONONGAHELA RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Monongahela River	7,400	128	0
Youghiogheny River	1,768	135	16
Cheat River	1,424	75	89
Tygart Valley River	1,369	130	128
West Fork River	882	80	128

MONONGAHELA RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
McKeesport 1/	Allegheny	Pennsyl.	42,694	46,781	54,632	55,355	51,502	45,489
Clarksburg	Harrison	West Va.	9,201	27,869	28,866	30,579	32,014	28,112
Morgantown	Monongalia	" "	9,150	12,127	16,186	16,655	25,525	27,487
Fairmount	Marion	" "	9,711	17,851	23,159	23,105	29,346	27,477
West Mifflin 1/	Allegheny	Pennsyl.	-	-	-	-	17,985	27,289
Baldwin 1/	"	"	-	-	-	-	-	24,489
Bethel Park 1/	"	"	-	-	-	-	11,324	23,650
Monroeville 1/	"	"	-	-	-	-	-	22,446
Monessen	Westmoreland	"	11,775	18,179	20,268	20,257	17,896	18,424
Clairton 1/	Allegheny	"	3,326	6,624	15,291	16,381	19,652	18,389
Uniontown	Fayette	"	13,344	15,692	19,544	21,819	20,471	17,942
Greensburg 1/	Westmoreland	"	13,012	15,033	16,508	16,743	16,923	17,383
Munhall 1/	Allegheny	"	5,185	6,418	12,995	13,900	16,437	17,312
Jeannette 1/	Westmoreland	"	8,077	10,627	15,126	16,220	16,172	16,565
Whitehall 1/	Allegheny	"	-	-	-	-	7,342	16,075
Swissvale 1/	"	"	7,381	10,908	16,029	15,919	16,488	15,089
Duquesne 1/	"	"	15,727	19,011	21,396	20,693	17,620	15,019
Brentwood 1/	"	"	-	1,695	5,381	7,552	12,535	13,706
North Braddock 1/	"	"	11,824	14,928	16,782	15,679	14,724	13,204
Dormont 1/	"	"	1,115	6,455	13,190	12,974	13,405	13,098
Connellsville	Fayette	"	12,845	13,804	13,290	13,608	13,293	12,814
Braddock 1/	Allegheny	Pennsyl.	19,357	20,879	19,329	18,326	16,488	12,337
Castle Shannon 1/	"	"	-	2,353	3,810	3,970	5,459	11,836
Donora	Washington	"	8,174	14,131	13,905	13,180	12,186	11,131
Turtle Creek 1/	Allegheny	"	4,995	8,138	10,690	9,805	12,363	10,607

1/ Part of Pittsburgh, Pennsylvania urbanized area.

TABLE 4

MONONGAHELA RIVER BASIN

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Mini. Pool Area (acres)	Storage (acre-feet) Max.Flood Control	Water Supply	Maximum Summer
Lake Lynn	P	1,730			248,770
Tygart Reservoir	F, N, P	620	278,000		109,600
Youghiogheny Res.	F, A	450	151,000		154,500
Deep Creek Res.	P	4,500			93,000

F - Flood Control
N - Navigation
P - Hydroelectric Power
A - Low Flow Regulation

TABLE 5

MONONGAHELA RIVER BASIN

Flow Data 4/

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Day Low Flow (cfs)
Monongahela River						
Hoult, W. Va.-Lock 15	2,388	4,120	33	91,500	99	
Greensboro, Pennsylvania	4,407	8,168	204	140,000	384	208
West Fork River						
Butchersville, W. Va.	181	305	0	18,000	.2	
Clarksburg, W. Va.	384	599 3/	0	16,900	2.3 5/	
Enterprise, W. Va.	759	1,170	3.4	31,400	11	4.9
Cheat River						
Parsons, W. Va.	718	1,656	9	52,100	33	17
Rowlesburg, W. Va.	972	2,222	10	66,300		
Pisgah, W. Va.	1,354	2,988	13	127,000		
Tygart River						
Belington, W. Va.	408	798	0.1	18,400	4.2	1.4
Phillipi, W. Va.	916	1,824	4.9	33,600	8	2.7
Grafton, W. Va. 1/	1,184	2,294 3/	0	20,000	170	
Colfax, W. Va.	1,366	2,607 3/	94	22,500	192	125
Youghiogheny River						
Youghiogheny River Dam, Pennsylvania	463	850	0	13,700		
Connellsville, Pennsylvania 2/	1,326	2,503	11	103,000	75	27

1/ Low flow regulated by Tygart Reservoir since 1938.
2/ Low flow regulated by Deep Creek Reservoir since 1925 and by Youghiogheny Reservoir since 1943.
3/ Unadjusted.
4/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey"
5/ Diversion above for water supply.

TABLE 6

MONONGAHELA RIVER BASIN

Economic Subarea B
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation B-1									
Pennsyl.	Fayette	169,300	51,000						
"	Greene	39,400	5,200						
West Va.	Harrison	77,900	35,000						
"	Lewis	19,700	8,800						
"	Marion	63,700	30,500						
"	Monongalia	55,600	27,200						
"	Taylor	15,000	5,800						
	Subtotal	440,600	163,500	478,120		534,500		570,000	
Area Designation B-2									
West Va.	Barbour	15,500	0						
Maryland	Garrett	20,400	0						
West Va.	Preston	27,200	2,500						
"	Randolph	26,300	8,300						
"	Tucker	7,800	0						
"	Upshur	18,300	6,400						
	Subtotal	115,500	17,200	128,410		152,240		180,000	
Total Subarea B		556,100	180,700	606,530	196,000	686,740	252,000	750,000	358,000

TABLE 7

MONONGAHELA RIVER BASIN

Economic Subarea B
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation B-1													
Pennsyl.	Fayette	45,900	11,520										
"	Greene	11,300	1,050										
West Va.	Harrison	25,200	6,340										
"	Lewis	5,800	1,040										
"	Marion	21,100	4,900										
"	Monongalia	17,600	2,970										
"	Taylor	3,900	500										
	Subtotal	130,800	28,320	583.5	118	120	188	145	141	322	184	165	536
Area Designation B-2													
West Va.	Barbour	3,900	330										
Maryland	Garrett	5,700	1,010										
West Va.	Preston	7,300	1,000										
"	Randolph	7,400	1,490										
"	Tucker	2,100	560										
"	Upshur	5,000	520										
	Subtotal	31,400	4,910	91.1	130	148	230	175	193	420	234	244	746
Total Subarea B		162,200	33,230	674.6	121	124	194	151	148	362	206	176	565

*In millions of 1960 dollars.
**1960 = 100

TABLE 8

MONONGAHELA RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Pennsylvania	Allegheny	C	Pittsburgh SMSA
West Virginia	Pocahontas	G-6	Kanawha-Little Kanawha
Pennsylvania	Somerset	A-2	Allegheny
"	Washington	C	Pittsburgh SMSA
"	Westmoreland	C	Pittsburgh SMSA

TABLE 9

MONONGAHELA RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation B-1											
Pennsyl.	Fayette	21	104,232	1,880	102,352	13.313	.118	13.195	128	Monongahela R., Youghiogheny R., Laurel McCoy Run, Wells and Springs	2.0
"	Greene	7	16,725	1,800	14,925	1.222	.359	.863	73	Monongahela R., Wisecarver R., Wells	0
West Va.	Harrison	5	41,375	2,365	39,010	3.287	.167	3.120	79	West Fork R., Jones Run, Wells	9.4
"	Lewis	2	9,425		9,425	.510		.510	54	West Fork R., Hackers Creek	0.4
"	Marion	6	63,950	3,800	60,150	7.375	.455	6.920	115	Monongahela R., Tygart Valley River, Tygart River, Wells	0
"	Monongalia	6	37,260	100	37,160	4.411	.007	4.404	118	Monongahela River, Dunkard Crk., Wells	10.6
"	Taylor	2	8,075	75	8,000	2.005	.005	2.000	248	Tygart Lake, Wells	0
	Subtotal	49	281,042	10,020	271,022	32.123	1.111	31.012	114		22.4
Area Designation B-2											
West Va.	Barbour	3	4,750	550	4,200	.356	.039	.317	75	Tygart Valley R., Tygart R., Springs	0
Maryland	Garrett	5	5,550	3,350	2,200	.501	.251	.250	90	Youghiogheny R., Springs, Wells	.1
West Va.	Preston	7	6,440	2,180	4,260	.477	.165	.312	74	Ashpola Run, Elsey Crk., Wells	1.0
"	Randolph	6	13,240	325	12,915	1.436	.031	1.405	109	Tygart River, Wells	0
"	Tucker	6	4,560	300	4,260	.526	.021	.505	115	Elk Lick Run, Creek No. 9, Weimers Run, Well	0
"	Upshur	1	8,000		8,000	.620		.620	78	Buckhannon River	0
	Subtotal	28	42,540	6,705	35,835	3.916	.507	3.409	92		1.1
Other Areas in Basin											
Pennsyl.	Allegheny	8	590,000	17,500	572,500	74.700	1.400	73.300	127	Monongahela R., Youghiogheny R., Wells	4650.0
"	Somerset	9	18,615	7,915	10,700	1.630	.583	1.047	88	Springs, Laurel Hill, Piney, Drake & Bigby Runs	0
"	Washington	14	107,400	2,750	104,650	9.773	.152	9.621	91	Monongahela R., Pigeon Crk., Cross Crk., Ten Mile Crk., Well, Springs	0.3
"	Westmoreland	10	184,400	900	183,500	19,646	.073	19.573	107	Youghiogheny, Beaver Crk., Jacobs Crk., Howells Run, Spring, Wells	43.7
	Subtotal	41	900,415	29,065	871,350	105.749	2.208	103.541	117		4694.0
	TOTAL	118	1,323,997	45,790	1,178,207	141.788	3.826	137.962	107		4717.5

TABLE 10

MONONGAHELA RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation B-1												
From Central Supplies	281,042	114	32.1	300,700	126	38.0	382,000	139	53.0	531,000	151	80.0
Industrial			22.4			33.5			63.0			78.0
Subtotal			54.5			71.5			116.0			158.0
Area Designation B-2												
From Central Supplies	42,540	92	3.9	46,800	102	4.8	63,000	111	7.0	97,000	124	12.0
Industrial			1.1			2.2			3.5			5.0
Subtotal			5.0			7.0			10.5			17.0
Other Areas in Basin												
From Central Supplies	900,415	117	105.7	971,400	130	126.0	1,123,000	142	160.0	1,328,000	158	210.0
Industrial			4694.0			5540.0			7135.0			9950.0
Subtotal			4799.7			5666.0			7295.0			10,160.0
Monongahela River Basin												
From Central Supplies Total	1,323,997	116	141.7	1,318,900	128	168.8	1,568,000	140	220.0	1,956,000	154	302.0
Industrial Total			4717.5			5575.7			7201.5			10,033.0
GRAND TOTAL			4859.2			5744.5			7421.5			10,335.0

TABLE 12

MONONGAHELA RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation B-1						
Pennsyl.	Fayette	27	101,315	Redstone Crk.Monongahela River, Youghioheny River	101,315	36,700
"	Greene	12	21,015	S.Fk.10 Mile Crk., Dunkard Creek, Monongahela River	21,015	3,800
West Va.	Harrison	7	33,180	Elk Crk.,Salem Crk.,West Fork River	33,180	11,800
"	Lewis	2	8,805	W.Fork River, Hackers Creek	8,805	1,100
"	Marion	8	35,606	Monongahela River, Paw Paw Creek, Buffalo Creek	35,606	6,600
"	Monongalia	4	28,225	Monongahela River	28,225	4,900
"	Taylor	1	7,431	Three Fork and Barkley Creeks	7,431	400
	Subtotal	61	235,577		235,577	65,300
Area Designation B-2						
Maryland	Barbour	3	3,855	Tygart River, Mill Run	3,855	0
"	Garrett	2	2,440	L.Youghiogheny R.,Casselman River	2,440	2,000
West Va.	Preston	8	7,415	Greens Run, Snowy Crk., Cheat River	7,415	7,100
"	Randolph	3	9,049	Tygart River, Mill Creek	9,049	3,800
"	Tucker	3	3,684	Dry Frk., N.Fork Blackwater River	3,684	700
"	Upshur	1	4,450	Buckhannon River	4,450	500
	Subtotal	20	30,893		30,893	14,100
Other Areas in Basin						
Pennsyl.	Allegheny	22	188,405	Monongahela, R.,Thompson Run, Peters Creek, Lick Creek	188,405	105,700
"	Somerset	8	14,465	E.Br.Coxes Crk., Casselman River, Buffalo Creek	14,465	4,100
"	Washington	25	58,060	Monongahela River, Pigeon Creek	58,060	13,500
"	Westmoreland	28	132,945	Zeller Run, Brush Run, Sewickley Crk., Jacks Run	132,945	45,600
	Subtotal	83	393,875		393,875	168,900
	TOTAL	164	660,345		660,345	248,300

*NOT to be interpreted as waste loads to the stream.

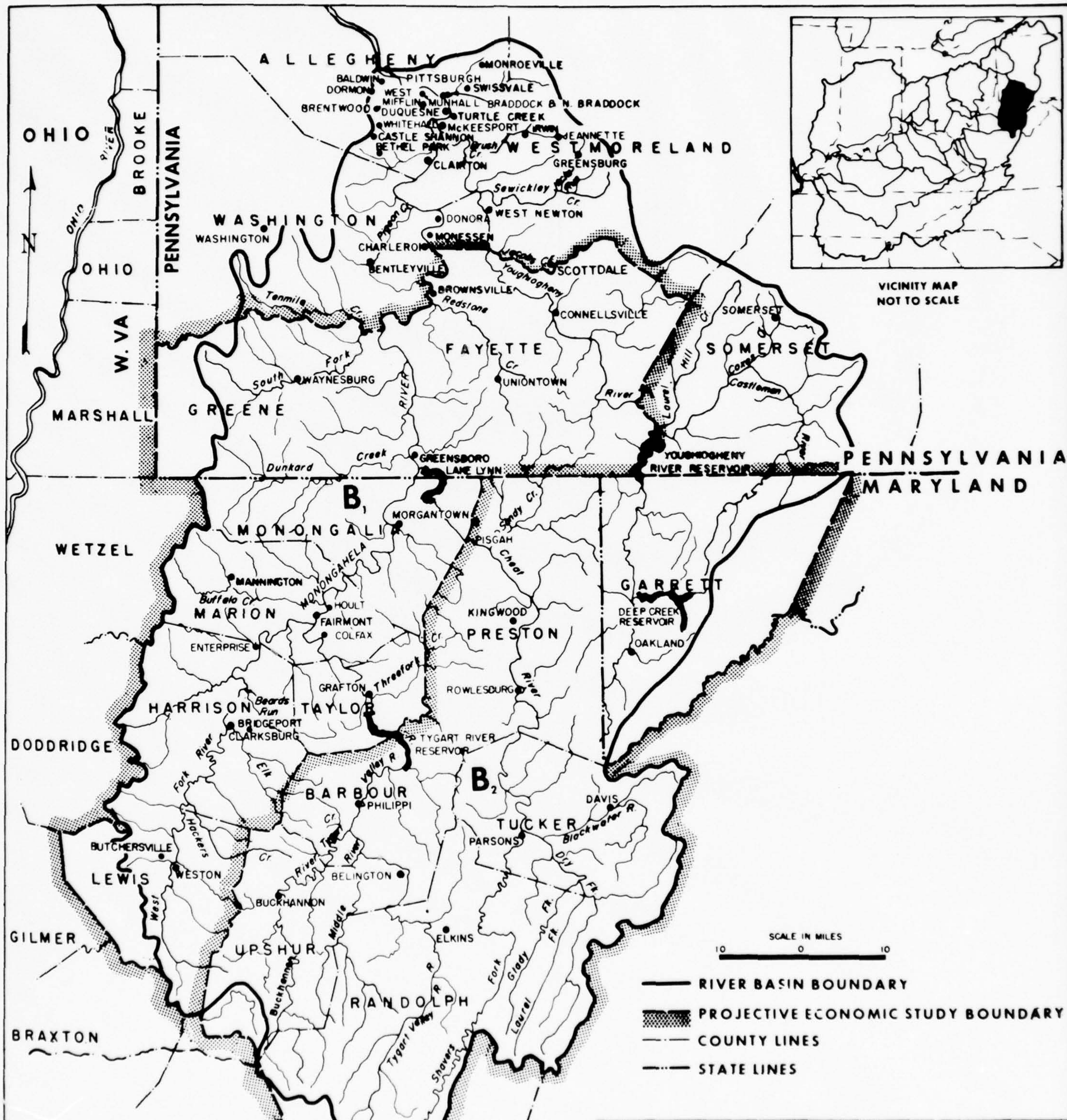
TABLE 13

MONONGAHELA RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation B-1				
Domestic and Commercial	235,577	252,100	320,400	445,000
Industrial	65,300	100,600	184,100	229,000
Subtotal	300,877	352,700	504,500	674,000
Area Designation B-2				
Domestic and Commercial	30,893	34,000	45,700	71,000
Industrial	14,100	26,600	43,100	63,000
Subtotal	44,993	60,600	88,800	134,000
Other Areas in Basin				
Domestic and Commercial	393,875	429,300	496,300	587,000
Industrial	168,900	199,300	256,700	358,000
Subtotal	562,775	628,600	753,000	945,000
Monongahela River Basin				
Domestic and Commercial Total	660,345	715,400	862,400	1,103,000
Industrial Total	248,300	326,500	483,900	650,000
GRAND TOTAL	908,645	1,041,900	1,346,300	1,753,000

*NOT to be interpreted as waste loads to the stream.



OHIO RIVER BASIN FRAMEWORK STUDY

MONONGAHELA RIVER BASIN LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 2.1

BEAVER RIVER BASIN

Subbasin Area
No. 3

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I SUMMARY

Municipal and Industrial Water Supply Problems

Major municipal water use in the basin occurs in the Mahoning River subbasin in the Warren to Youngstown, Ohio reach. The major portion of the water used is from surface sources, primarily from impoundments on tributary streams. In the upper Mahoning River Basin, Alliance uses both ground and surface sources. The major industrial water use is for cooling purposes and is located in this same reach of stream. The principal source of water is the Mahoning River, augmented during low flow periods by releases from multipurpose reservoirs.

In other areas in the Beaver River Basin, major withdrawals from surface sources occur in Pennsylvania at Butler from Connoquenessing Creek (Butler also pumps municipal water from the Allegheny River), at Ellwood City from Slippery Rock Creek, at Mercer from Otter Creek, at New Castle and Sharon from the Shenango River, at Greenville from a tributary of the Little Shenango River and at Beaver Falls from the Beaver River.

Based on data of dependable yields from existing surface impoundments and projected water use, it is estimated that by 1980 additional municipal water supply sources should be developed to meet the needs at Warren, Alliance, Youngstown and other communities served by the Mahoning Valley Sanitary District.

Water Quality Control Problems

Because of present industrial water use practices, even with low flow stream regulation, excessive stream temperatures exist in the Mahoning River, indicating a high reuse of water from the stream for cooling purposes. This condition could be improved by utilization of off-stream cooling water facilities. An adequate supply of water is available in the stream for the higher makeup losses.

The major problem area in the Beaver River Basin is in the reach of the Mahoning River from Warren downstream to Youngstown, Ohio.

The quality of water in the Mahoning River has been degraded by the discharge of inadequately treated organic wastes from municipal and industrial sources, the discharge of excessive heat loads from industry and the discharge of inorganic wastes from industries in the area. Assuming secondary treatment of organic wastes, control of inorganic discharges and reduction of heat loads at the source by off-stream cooling methods, low flow augmentative release from existing reservoirs are adequate at the present to assimilate residual organic wastes. However, with projected population increase and increased industrial activity, increased summer flows will be required starting in 1980.

Another area in the basin where stream conditions are unsatisfactory at the present during low flow periods is the Mahoning River below Alliance, Ohio.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Beaver River Basin is located in northeastern Ohio and northwestern Pennsylvania. The Beaver River is formed by the confluence of the Mahoning River and Shenango River near New Castle, Pennsylvania, and flows in a southerly direction for about 21 miles, where it enters the Ohio River at Rochester, Pennsylvania, approximately 25 river miles below Pittsburgh. The Mahoning River rises south of Alliance, Ohio, flows northeast to Warren, Ohio, where it turns to the southeast and flows through Youngstown, Ohio and across the Ohio-Pennsylvania line to join the Shenango River. The Shenango River rises in Pennsylvania, flows northwest to the Ohio-Pennsylvania border then turns and flows generally south to the confluence with the Mahoning River. The total drainage area of the basin is 3,130 square miles, covering parts of the 13 counties in the two States listed in Table 1.

The main tributaries comprising the Beaver River system are shown in Table 2.

Physical Features

The Beaver River Basin is situated in the Appalachian Plateau province of the Appalachian Highlands physiographic division. The topography of the northern and western portions of the basin has been changed by the continental ice sheets, which rounded the hills and filled most of the bedrock valleys with thick deposits of glacial sediments, generally clay and fine sand. The southeastern part of the basin drained by Connoquenessing Creek is unglaciated and is dissected plateau.

There are no natural lakes in the basin. In the Mahoning River Basin, two major bodies of water, Berlin and Mosquito Creek Reservoirs, were created by dams constructed by the Corps of Engineers for flood control, water supply and low flow regulation. Milton Reservoir was constructed by the city of Youngstown and private interests for the purpose of augmenting low flow in the Mahoning River. Meander Creek Reservoir, a water supply reservoir constructed by the Mahoning Valley Sanitary District, and West Branch Reservoir, now under construction by the Corps of Engineers, will regulate flows in the Mahoning River. In the Shenango River Basin, Pymatuning Reservoir

was built by the State of Pennsylvania for the primary purpose of recreation. Shenango Reservoir is being constructed by the Corps of Engineers for flood control and flow regulation. There are also a number of smaller reservoirs constructed for water supply and recreation purposes.

Climate

The average annual precipitation is about 35 inches generally well distributed throughout the year.

Average minimum monthly temperature is about 27°F in January with the average maximum monthly temperature about 72°F in July. The frost-free season averages about 150 days throughout the basin.

Principal Communities and Industries

Agriculture in the basin consists primarily of the dairy industry, stock raising, poultry raising, truck crops and fruit.

Limestone is produced in Mahoning County, Ohio and is used for concrete and road metal, for fluxing and for agricultural limestone. Coal in Mahoning County is obtained primarily from strip mining operations and is mined in most of the other counties in the Beaver River Basin by either strip or auger methods.

Industry in the Beaver River Basin centers around the production of steel and the fabrication and finishing of steel products. In the Mahoning River subbasin, major components of the industry are located in the Youngstown to Warren reach. The primary steel industry and fabrication of steel products is important to all of the principal communities located in the Shenango River subbasin and on the Beaver River main stem.

Listed in Table 3 are some of the principal cities and their populations from 1910 to the present time.

III WATER RESOURCES

Surface Water Resources

Quantity

Surface flows in the Mahoning River Basin are affected by reservoirs constructed on the Mahoning River and several tributary streams. Milton Reservoir on the Mahoning River, constructed by the city of Youngstown and local interests on the Mahoning River above Warren, Ohio, began operation in 1917. Berlin Reservoir, located on the Mahoning River above the Milton Reservoir, and Mosquito Creek Reservoir, located on Mosquito Creek, were constructed by the Corps of Engineers and began operation in 1943 and 1944 respectively. These three reservoirs are operated for flood control, low flow regulation and water supply. The Mosquito Creek Reservoir provides up to 16 mgd to the city of Warren. The Meander Creek Reservoir, owned by the Mahoning Valley Sanitary District, is operated as a water supply reservoir. In 1958, a pipeline was constructed from Berlin Reservoir to Meander Creek Reservoir for additional water supply. The safe yield for the combined impoundments is 64 mgd. There are eight water supply reservoirs owned and operated by the Ohio Water Service Company, a private utility serving both industry and municipalities in a twelve-mile stretch of the Mahoning River above the Ohio-Pennsylvania boundary line. The safe yield of these impoundments is 27 mgd. In the upper Mahoning River Basin, Alliance, Ohio, has two reservoirs for water supply with a safe yield of 6 mgd. In addition to the reservoirs described above, West Branch Reservoir on West Branch Mahoning River is under construction by the Corps of Engineers, and will be operated for flood control and low flow regulation. Newport Lake on Mill Creek in Mahoning County is operated as a recreation lake.

In the Shenango River subbasin the Pymatuning Reservoir is located on the Ohio-Pennsylvania State line on the Shenango River. It was constructed by the State of Pennsylvania primarily for recreation and is operated for flood control and low flow regulation of the Shenango and Beaver Rivers. The Shenango Reservoir, now under construction by the Corps of Engineers, is located below the Pymatuning Reservoir above Sharon, Pennsylvania, on the Shenango River and will be operated for flood control and low flow regulation. Table 4 shows pertinent data regarding these impoundments.

Although much of the basin is glaciated, sustained flows are relatively low, indicating a rather limited potential for ground water development basinwide, although in some areas the glacial drift includes some prolific aquifers.

In Table 5 are shown stream data excerpted from data prepared by the Corps of Engineers.1/

Quality

Surface waters in the basin, in their natural state, are primarily hard waters of the calcium magnesium bicarbonate or calcium magnesium sulfate type ranging from 100 to 200 mg/l. In addition to natural variations, changes in quality are often the result of domestic and industrial wastes, especially in the reach of the Mahoning River below Warren, Ohio. At Lowellville near the Ohio-Pennsylvania border, ammonia (NH_4) from October 1956 to June 1960 averaged 3 to 4 mg/l with a maximum of 12 mg/l. The water most of the time is slightly acid and has undesirable concentrations of iron which at times are over 10 mg/l. Phenol concentrations often were objectionable. Thermal pollution is also extreme with temperatures in the stream exceeding 93°F during the warmer months.

Ground Water Resources

Quantity

Ground water resources have been reported by the U. S. Geological Survey2/ and the following discussion has been condensed from their report.

Most of the area drained by the Beaver River is underlain by glacial deposits ranging in thickness from a few feet to 350 feet or more. Over most of the glaciated areas, outside of river valleys, glacial sediment consists of sand, gravel, and boulders in a matrix of clay. This material for the most part has low permeability, although in a few localities small lenses of permeable sand and gravel are interbedded with till and yield moderate supplies of water of less than 100 gpm to individual wells. Due to their irregular distribution and composition, their yield of water may vary from place to place, being greatest where coarser and thicker.

Long reaches of major stream valleys are filled with glacial outwash. The outwash is composed generally of fine sand and has not

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

been favorable for large scale development. In a few places rather thick beds of permeable gravel exist and serves as a source of water yielding up to 600 gpm to individual wells. A detailed ground water investigation of the Beaver River Basin should precede any planning for greater utilization of the basin's water resources by large scale developments.

Bedrock formations consist of Paleozoic sedimentary rocks consisting largely of sandstones and shales that dip very gradually toward the south. The most favorable area for potential development of water supplies from bedrock formation occurs in the northern part of the basin, where yields to individual wells of from 100 to 200 gpm can be anticipated.

Quality

Little or no data regarding chemical analyses of water from unconsolidated glacial deposits are available, but chemical characteristics of ground water in this basin probably are similar to those of adjacent basins. The water is probably hard and high in dissolved solids. Hardness is probably of the calcium magnesium bicarbonate type ranging from 100 to 400 mg/l and total dissolved solid content ranging from 200 to 600 mg/l. Iron is probably present in undesirable quantities exceeding the 0.3 mg/l suggested by the Public Health Service Drinking Water Standards.

While most water supplies derived from the glacial drift are not suitable for drinking water in their natural state, they can be upgraded in quality by common treatment processes. Elsewhere in the northern part of the Ohio River Basin and throughout glaciated areas of the United States, the glacial drift is probably the most important source of ground water.

Water from bedrock formations is generally hard, ranging from 80 to 200 mg/l, with dissolved solids ranging from 200 to 700 mg/l. Iron is usually present in undesirable quantities ranging upward to about 3 mg/l, but also may be readily treated.

IV THE ECONOMY

The Beaver subarea of the Projective Economic Study is generally coextensive with the watershed of the Beaver River with the exception of its extreme lower reaches. Two counties, Trumbull and Mahoning, of this five-county area lie in Ohio and are designated a Standard Metropolitan Statistical Area. The remaining three counties lie in Pennsylvania and are within the area designated as Appalachia. The counties in the subarea are listed in Tables 6 and 7 and are shown on Figure 3-1, page 3-29.

Economic Profile

The Beaver subarea is a heavily industrialized area with a 1960 population of 864,100, 59 percent of which resided in the two Ohio counties, Trumbull and Mahoning. Per capita personal income averaged $1,906 in these counties as compared with $1,957 for the State of Ohio and $1,721 in the remaining counties as compared to $1,855 for the State of Pennsylvania.

Forty-four percent of total employment was in manufacturing in 1960. The most important industries are primary metals, machinery (including electrical machinery), fabricated metals, and other durables. Between 1958 and 1964, establishments hiring 100 workers or over increased from 97 to 120, with Trumbull and Mahoning Counties accounting for 12 of the 23 additional establishments.

Ten thermal power generating plants are located in the subarea with a total installed capacity of 767.1 megawatts. Location of the plants is described in Section VI, Water Quality Control.

Agricultural employment has declined 4.8 percent per annum from 1950 to 1960. The total value of farm products sold in 1959 amounted to $43,000,000 or $3,000,000 more than in 1954. The number of acres irrigated decreased during the above years from 500 acres to 250 acres.

Bituminous coal and crude oil extraction are the most significant categories in mining in the area. In 1960, 4.6 million tons of coal were mined in the subarea, of which 0.9 million tons of coal were mined in Mahoning County, Ohio, with the remainder mined in the

Pennsylvania counties. Crude oil production in the Pennsylvania counties amounted to 166,000 barrels representing 2.8 percent of the total State production.

Projected Population and Industrial Activity

Population, as shown in Table 6, is expected to increase from 864,100 in 1960 to 1.4 million by 2020. Whereas the population in the subarea amounted to 4.6 percent of the total population in the Ohio River Basin in 1960, it is projected to contain 4 percent of the Ohio River Basin by 2020.

Agricultural output is projected to decrease from $65.4 million in 1960 to $55.6 million by 1980 and then increase to $61.8 million by 2000. Manufacturing output is projected to increase from $3,196 million in 1960 to $7,872 million by 2000.

Table 7 shows 1960 manufacturing output total employment and manufacturing employment. Projections to 1980, 2000, and 2020 for the subarea are shown as indices using 1960 as the base.

In addition to the counties included in the Beaver subarea in the Projective Economic Study, eight other counties have land area within the basin. These counties are listed in Table 8.

V WATER REQUIREMENTS-MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

There are 48 central water supply systems in the Beaver River Basin serving a population of 720,000. The average daily municipal water use is 84 mgd amounting to 117 gallons per capita daily use. The present (1960) municipal and industrial water use in the basin is listed by county and totaled for the basin in Table 9.

In the basin, about 88 percent of the water used for municipal supplies is from surface sources. The Mahoning Valley Sanitary District in Ohio utilizes surface water from Meander Creek and Berlin Reservoirs, which together have a safe yield of 64 mgd. The district serves the communities of Youngstown, McDonald, Niles, Girard and Canfield and three Mahoning County sanitary districts located along the Mahoning River. These communities use an average of 31 mgd and account for over 40 percent of the total municipal water use from surface sources in the basin.

Another large municipal supply in the Mahoning River Basin is for Warren, Ohio, serving a population of 70,000 with an average of 9 mgd from Mosquito Creek Reservoir which has a safe yield of 16 mgd.

In Pennsylvania, major withdrawals are made by Butler from Connoquenessing Creek and Allegheny River, by Ellwood City from Slippery Rock Creek, by New Castle and Sharon from the Shenango River and Beaver Falls from the Beaver River.

In other areas in the basin not included in the boundaries of the Beaver River subarea of the Projective Economic Study, the largest municipal water use is at Alliance, Ohio, utilizing both ground water from wells and surface water from the city owned Deer Creek and Westville Reservoirs.

Practically all of the smaller communities in the basin use ground water sources.

Industrial water use is concentrated largely in the Mahoning River subbasin, where the industries in Mahoning and Trumbull Counties in Ohio account for over 86 percent of the industrial water use in the Beaver River Basin.

Based on projected population increase and projected industrial activity, water use is estimated to increase in the Beaver River as shown in Table 10. It is estimated that total municipal and industrial water requirements will increase 2.5 times by 2020. The major increases will probably occur in or about present centers of population and industrial activity in the Youngstown-Warren area in Ohio and in the Butler, Sharon, New Castle and Beaver Falls areas in Pennsylvania.

Water Supply Problems

The projected total water supply figures shown in Table 10, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11 are the major problem areas with the approximate time of onset.

TABLE 11

BEAVER RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Mahoning Valley San.Dist.,Ohio	D		X		
Warren, Ohio	D		X		
Youngstown, Ohio	D		X		
Alliance, Ohio	F-3		X		

In subarea D, total water use is projected to increase to 1,289 mgd by 1980, to 1,775 mgd by 2000 and about 2,600 mgd by 2020. About 93 percent of the projected water use will be for industrial purposes. Projections of industrial usage are based on present water use, assuming continuation of present industrial water use practices. About 95 percent of the industrial water is used for cooling in the reach of the Mahoning River between Lowellville and Warren.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The average annual flow of the Mahoning River is less than the industrial use in the area; therefore, reuse of streamflow is very high during periods of lower flows. If industrial cooling practices would be changed and off-stream cooling facilities were utilized, the requirements for industrial water in the future would be drastically reduced from projected figures.

Municipal water use is projected to increase to 89 mgd in 1980, 125 mgd in 2000, and 183 mgd in 2020. In the lower Mahoning River subbasin, below Warren, because of surface water impairment resulting from both municipal and industrial sources of pollution, municipal water supplies are no longer taken from the stream. Municipal water supplies for the communities along this reach of stream are principally taken from upland reservoirs. The Youngstown-Niles area, served by the Mahoning Valley Sanitary District, obtains its water supplies from a reservoir on Meander Creek supplemented by a pipeline from Berlin Reservoir. The city of Warren takes its water supply from Mosquito Creek Reservoir. By 1980 it is estimated that additional sources of water supplies will have to be developed, in order to meet the peak needs in the Warren-Niles-Youngstown area. Possible reservoir sites in the area are limited since the major sites have already been developed. A reservoir on the Grand River (which drains to Lake Erie) could supply water to the northern communities in the basin, and a divide reservoir on the Middle Fork of Little Beaver Creek could supply water for the southern communities. Other sites for reservoirs are on the upper reaches of Pymatuning Creek, Yankee Creek, Mill Creek and Eagle Creek.

Alliance, presently using both surface and ground water sources, will probably need to develop additional sources by 1980. Indications are that intermediate yielding sources of ground water exist in the bedrock and glacial outwash in the tributary valleys but may have to be supplemented by surface water development if large supplies are needed. Surface water in this headwaters area, must be provided by construction of additional impoundments or by reallocation of storage in Federal multipurpose reservoirs.

In the portion of the basin drained by the Shenango River and its tributaries and in the Slippery Rock Creek drainage area, raw water for municipal supply is taken from surface sources which appear to be adequate to meet projected needs to 2020, provided quality of the water is preserved. In the lower Beaver River, the Beaver Falls Municipal Authority obtains its water supply from the

Beaver River. While there is no problem now or in the foreseeable future as far as quantity of water is concerned, the quality of the water, due to waste loads discharged into the Mahoning River, is such that severe water treatment problems have been encountered. Alternate sources of supply could probably be developed in upland reservoirs and possibly by recharge from unconsolidated glacial and alluvial deposits in the river valley.

Undoubtedly there are smaller communities which will have water problems, but it is beyond the scope of this report to define each problem area in detail.

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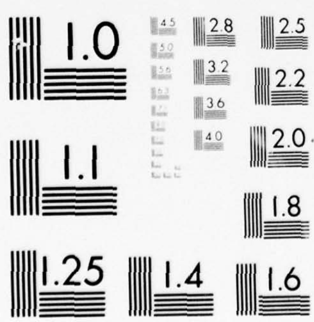

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

Present raw waste loads generated are shown in Table 12. About 85 percent of the total organic waste load generated in the basin are accounted for in area designation D. Mahoning and Trumbull Counties, Ohio account for 65 percent of the raw wastes generated in area designation D. The Warren-Youngstown reach of the Mahoning River is a major water quality problem area in the Beaver River Basin.

Major discharges to streams in Pennsylvania are from Butler on Connoquenessing Creek, Sharon and New Castle on the Shenango River and Beaver Falls-New Brighton on the Beaver River.

Shown in Table 13 are the base and projected waste loads generated for the basin. Waste loads generated are projected to more than double by 2020.

Water Quality Control Problems

Table 14 lists the present and projected water quality control problem areas after secondary treatment or equivalent reduction of organic wastes is provided.

TABLE 14

BEAVER RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date			
			Present	1980	2000	2020
Mahoning River	Alliance, O.	F-3	X			
" "	Warren, O.	D		X		
" "	Youngstown, O.	D		X		
Connoquennessing Creek	Butler, Pa.	D		X		

The major water quality control problem in the basin is in the Mahoning River in the Warren to Youngstown reach. In the area draining to this stream, population expansion and industrial growth has far exceeded the capacity of the stream to assimilate residual organic waste loads and dissipate heat loads. The low flow in the stream at Youngstown prior to construction of reservoirs to augment streamflows was in the order of 10 to 20 cfs. River temperatures at Youngstown reached as high as 130°F in the summer when streamflows were less than 40 cfs. Flow regulation provided by Berlin and Mosquito Creek Reservoirs for the purpose of controlling temperatures for industrial water supply use prevented such extremely high temperatures, although it is estimated that water temperatures may still rise to about 112°F for periods up to a week in duration in the summer season if steel mills are operating at about 85 percent of capacity. In addition to heat from industrial process cooling, there are major thermal power generating plants in the subbasin. Plants with capacities of 250 megawatts, 87.4 megawatts, 53.5 megawatts, 45 megawatts and two plants with a total capacity of 16.4 megawatts are located in the Warren to Youngstown reach and use surface water for cooling. Heat in cooling water discharged to the Mahoning River may be considered a pollutant since the ability of water to retain dissolved oxygen is related to the temperature of the water. In addition to reducing the dissolved oxygen available to assimilate residual wastes, the rate at which biochemical oxidation takes place is increased. Construction of the aforementioned reservoirs has resulted in increased minimum flows so that in the summer 470 cfs is available. With the addition of flows from West Branch Reservoir now under construction, minimum flows will be about 515 cfs. Assuming secondary treatment or equivalent reduction of organic wastes by both industry and municipalities and reduction of heat discharged by industry and thermal power generating plants to maintain stream temperatures at a maximum of 93°F, these flows should be sufficient at the present to maintain satisfactory conditions in the Mahoning River. However, by 1980 flows will have to be increased to 710 cfs, by 2000 to 805 cfs, and by 2020 to 875 cfs to maintain satisfactory conditions. As additional storage is probably not available above Youngstown, additional flow regulation is only a partial solution and advanced waste treatment methods will probably be required.

In other areas in the subbasin, indications are that additional flows are required in the Mahoning River below Alliance. Design flow is about 10 cfs, but flows in the order of 30 cfs at the present are needed, increasing to 45 cfs by 1980, to 60 cfs by 2000 and to 70 cfs by 2020. As Alliance is in the headwaters region of the Mahoning River

above Berlin Reservoir, storage of water for flow regulation may not be feasible. A possible solution could be to divert effluent flows around the reservoir and discharge to the stream below the dam.

In the Shenango River subbasin, flows of 200 cfs are released from Pymatuning Reservoir. With the completion of the Shenango Reservoir, flows released from the two reservoirs will total in the order of 300 cfs at Sharon and should be sufficient to maintain satisfactory stream conditions in the Shenango River at Sharon, Pennsylvania, and downstream points and in the Beaver River.

The major source of organic waste load discharges in Connoquenessing Creek is in the headwaters area at Butler, Pennsylvania, where design flow is less than 10 cfs. Flows in the order of 50 cfs are required at present, increasing to about 70 cfs by 2020.

Major source of heat discharge from a thermal power generating plant in the Shenango River subbasin is at New Castle, Pennsylvania, where a plant with a capacity of 293.0 megawatts uses surface water for cooling purposes. There is one small plant located at Farrell with a capacity of 7.5 megawatts.

In the Beaver River main stem drainage area, one plant with a capacity of 6.6 megawatts is located at Ellwood City and one plant with a capacity of 7.7 megawatts is located at Grove City on Wolf Creek.

Aside from the organic waste loads from both municipal and industrial sources in the Mahoning River Basin and also in the Beaver River Basin, many industries release waste water containing toxic metals, iron, manganese, acids, oils, etc., the concentrations of which are not expressable in terms of population equivalents as are organic wastes. This type of waste results from processing operations at steel mills, plating works, blast furnace installations and some metal fabricating establishments.

Mine drainage problems occur in a number of streams in the basin, notably Slippery Rock Creek and Connoquenessing Creek in Pennsylvania, the upper reaches of the Mahoning River and tributaries near Alliance, Ohio, and Mill Creek a tributary to the Mahoning River in the lower portion of the subbasin in Ohio.

TABLES

TABLE 1

BEAVER RIVER BASIN

Counties in Basin

State	County	Percent of Land Area in Basin
Pennsylvania	Allegheny	1.5
Ohio	Ashtabula	16.2
Pennsylvania	Beaver	27.7
" *	Butler	70.7
Ohio	Columbiana	7.2
Pennsylvania	Crawford	15.0
" *	Lawrence	89.6
Ohio *	Mahoning	82.2
Pennsylvania *	Mercer	84.2
Ohio	Portage	54.5
"	Stark	12.2
" *	Trumbull	76.6
Pennsylvania	Venango	2.2

*Counties considered in economic projections of Beaver River Basin.

TABLE 2

BEAVER RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Beaver River	3,130	21	0
Connoquenessing Creek	830	50	12
Mahoning River	1,131	108	21
Shenango River	1,080	60	21

TABLE 3

BEAVER RIVER BASIN

Populations of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Youngstown	Mahoning	Ohio	79,066	132,358	170,002	167,720	168,330	166,689
Warren	Trumbull	"	11,081	27,050	41,062	42,837	49,856	59,648
New Castle	Lawrence	Pennsyl.	36,280	44,938	48,674	47,638	48,834	44,790
Alliance	Stark	Ohio	15,083	21,603	23,047	22,405	26,161	28,362
Sharon	Mercer	Pennsyl.	15,270	21,747	25,908	25,662	26,454	25,267
Butler	Butler	"	20,728	23,778	23,568	24,477	23,482	20,975
Niles	Trumbull	Ohio	8,361	13,080	16,314	16,273	16,773	19,545
Beaver Falls 1/	Beaver	Pennsyl.	12,191	12,802	17,147	17,098	17,375	16,240
Struthers	Mahoning	Ohio	3,370	5,847	11,249	11,739	11,941	15,631
Farrell	Mercer	Pennsyl.	10,190	15,586	14,359	13,899	13,644	13,793
Campbell	Mahoning	Ohio	4,972	11,237	14,673	13,785	12,882	13,406
Girard	Trumbull	"	3,736	6,556	9,859	9,805	10,113	12,997
Elwood City	Beaver Lawrence	Pennsyl.	3,902	8,958	12,323	12,329	12,945	12,413

1/ Part of Pittsburgh, Pennsylvania urbanized area.

TABLE 4

BEAVER RIVER BASIN

Reservoirs - Area 90 Acres or Greater

Name	Purpose	Perm.Mini. Pool Area (Acres)	Storage (acre-feet) Max.Flood Control	Water Supply	Maximum Summer
Berlin	F, A, W	240	55,800	19,400	39,000
Milton	A	1,685			21,600
Mosquito Creek	F, A, W	700	33,000	11,000	71,400
Meander Creek	W	2,010		30,675	
West Branch 3/	F, A	580	33,200		56,700
Deer Creek	W	313		3,100	
Evans Lake	W	566		8,497	
Lake Girard	W	185		2,760	
Liberty Lake	W	99		595	
Lake Hamilton	W	104		2,270	
McKelvey Lake	W	125		3,310	
Pine Lake 1/	W	474		2,653	
Beaver Lake 2/	W	136		144	
Pymatuning Lake	F, A, R	14,650	194,000		160,000
Newport Lake	R	105			920
Westville	W	90			
Shenango 3/	F, A	1,910	180,900		41,400
Crooked Creek 3/4/	F, R	625	2,560		

F - Flood Control
A - Low Flow Augmentation
W - Water Supply
R - Recreation

1/ Straddles watershed. Artificially drained north to Mahoning River.
2/ Top six feet is artificially drained north to the Mahoning River.
3/ Under construction - 1966.
4/ P.L.566 Project.

TABLE 5

BEAVER RIVER BASIN

Flow Data 3/

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. 1/ Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Beaver River						
Wampum, Pennsylvania	2,235	2,365	74 2/	50,100	232 2/	
Mahoning River						
Youngstown, Ohio	899	844	28 2/	17,600	120 2/	
Lowellville, Ohio	1,076	1,078	125 2/	21,000		
Shenango River						
Sharpsville, Pa.	588	743	38	15,700	86	
West Branch, Mahoning River						
Newton Falls, Ohio	97.8	98.7	2.9	8,340	4.1	2.8

1/ Natural flow.
2/ Natural flow, including low flow regulation from Milton Reservoir.
3/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey."

TABLE 6

BEAVER RIVER BASIN

Economic Subarea D
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Pennsylvania	Butler	114,600	33,600						
"	Lawrence	113,000	59,400						
Ohio	Mahoning	300,500	251,600						
Pennsylvania	Mercer	127,500	68,600						
Ohio	Trumbull	208,500	139,700						
Total Subarea D		864,100	552,900	970,910	688,000	1,178,900	874,000	1,390,000	1,155,000

TABLE 7

BEAVER RIVER BASIN

Economic Subarea D
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Pennsylvania	Butler	38,000	14,200										
"	Lawrence	38,100	15,500										
Ohio	Mahoning	104,900	43,900										
Pennsylvania	Mercer	44,100	19,600										
Ohio	Trumbull	73,100	36,800										
Total Subarea D		298,200	130,000	3196.2	116	98	153	146	103	246	184	111	397

*In millions of 1960 dollars.
**1960 = 100

TABLE 8

BEAVER RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Pennsylvania	Allegheny	C	Pittsburgh SMSA
Ohio	Ashtabula	*	
Pennsylvania	Beaver	C	Pittsburgh SMSA
Ohio	Columbiana	E-2	Upper Ohio
Pennsylvania	Crawford	A-1	Allegheny
Ohio	Portage	*	
"	Stark	F-3	Muskingum
Pennsylvania	Venango	A-1	Allegheny

* - Not included in Projective Economic Study of Ohio River Basin.

TABLE 9

BEAVER RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation D											
Pennsyl.	Butler	10	45,850	8,650	37,200	5.167	.622	4.545	106	Connoquenessing Cr'., Scollars Run, Wells	100.0
"	Lawrence	8	98,790	7,290	91,500	10.026	.426	9.600	102	Slippery Rock Crk., Shenango R., Wells	7.0
Ohio	Mahoning	4	51,785	1,880	49,905	3.890	.090	3.800	75	Hamilton, McKelvey, Evans, and Burgess Lakes, Mahoning R., Wells	665.0
Pennsyl.	Mercer	10	90,115	12,715	77,400	10.200	1.306	8.894	113	Shenango R., Otter Crk., and Wells	8.0
Ohio	Trumbull	7	337,005	11,805	325,200 1/	41.783	.883	40.900	124	Meander Crk., Mosquito R., E.Branch Mahoning River, Wells	170.0
	Subtotal	39	623,545	42,340	581,205	71.066	3.327	67.739	104		950.0
Other Areas in Basin											
Ohio	Ashtabula	1	1,000	1,000		.180	.180		180	Wells	0
Pennsyl.	Beaver	2	49,000	4,000	45,000	6.160	.360	5.800	126	Beaver River, Wells	19.0
Ohio	Columbiana	1	4,390	4,390		.250	.250		57	Wells	.1
Pennsyl.	Crawford	1	1,100	1,100		.124	.124		113	Wells and Springs	.1
Ohio	Portage	3	5,100	5,100		.460	.460		90	Wells and Springs	1.0
"	Stark	1	35,850	35,850		5.620	5.620		157	Reservoir, Wells	.1
	Subtotal	9	96,440	51,440	45,000	12.794	6.994	5.800	133		20.3
	TOTAL	48	719,985	93,780	626,205	83.860	10.321	73.539	117		970.3

1/ Includes 210,000 population served in Mahoning County.

TABLE 10

BEAVER RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation D												
From Central Supplies	623,545	104	71.1	773,200	115	89.0	985,000	127	125.0	1,309,000	140	183.0
Industrial			950.0			1200.0			1650.0			2400.0
Subtotal			1021.1			1289.0			1775.0			2583.0
Other Areas in Basin												
From Central Supplies	96,440	133	12.8	143,700	146	21.0	179,000	160	28.5	232,000	164	38.0
Industrial			20.3			24.0			30.5			43.0
Subtotal			33.1			45.0			59.0			81.0
Beaver River Basin												
From Central Supplies Total	719,985	117	83.9	916,900	120	110.0	1,164,000	132	153.5	1,541,000	143	221.0
Industrial Total			970.3			1224.0			1680.5			2443.0
GRAND TOTAL			1054.2			1334.0			1834.0			2664.0

TABLE 12

BEAVER RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Areas	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation D						
Pennsyl.	Butler	8	47,220	Connoquenessing Crk., Breakneck Crk., and Slippery Rock Creek	47,220	19,400
"	Lawrence	8	82,325	Mahoning R., Connoquenessing Crk., Neshannock Creek	82,325	8,000
Ohio	Mahoning	7	223,890	Mahoning R., Sebring Br., Meander Crk.	223,890	128,400
Pennsyl.	Mercer	10	75,065	Shenango R., Wolf Crk., Neshannock Crk.	75,065	25,900
Ohio	Trumbull	7	109,035	Mahoning R., L.Yankee Crk., Mosquito Crk.	109,035	51,900
	Subtotal	40	537,535		537,535	233,600
Other Areas in Basin						
Ohio	Ashtabula	1	1,115	Br. of Shenango River	1,115	400
Pennsyl.	Beaver	6	48,620	Beaver River, Moon Run	48,620	20,200
Ohio	Columbiana	1	4,165	Mill Creek	4,165	0
Pennsyl.	Crawford	1	850	Pymatuning Reservoir	850	300
Ohio	Portage	3	6,445	Sand Crk., Eagle Crk.	6,445	0
"	Stark	1	28,400	Mahoning River	28,400	1,500
	Subtotal	13	89,595		89,595	22,400
	TOTAL	53	627,130		627,130	256,000

*NOT to be interpreted as waste loads to the stream.

TABLE 13

BEAVER RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation D				
Domestic and Commercial	537,535	666,500	849,300	1,129,000
Industrial	233,600	294,300	406,500	593,000
Subtotal	771,135	960,800	1,255,800	1,722,000
Other Areas in Basin				
Domestic and Commercial	89,595	111,100	141,600	188,000
Industrial	22,400	28,200	39,000	57,000
Subtotal	111,995	139,300	180,600	245,000
Beaver River Basin				
Domestic and Commercial Total	627,130	777,600	990,900	1,317,000
Industrial Total	256,000	322,500	445,500	650,000
GRAND TOTAL	883,130	1,100,100	1,436,400	1,967,000

*NOT to be interpreted as waste loads to the stream.

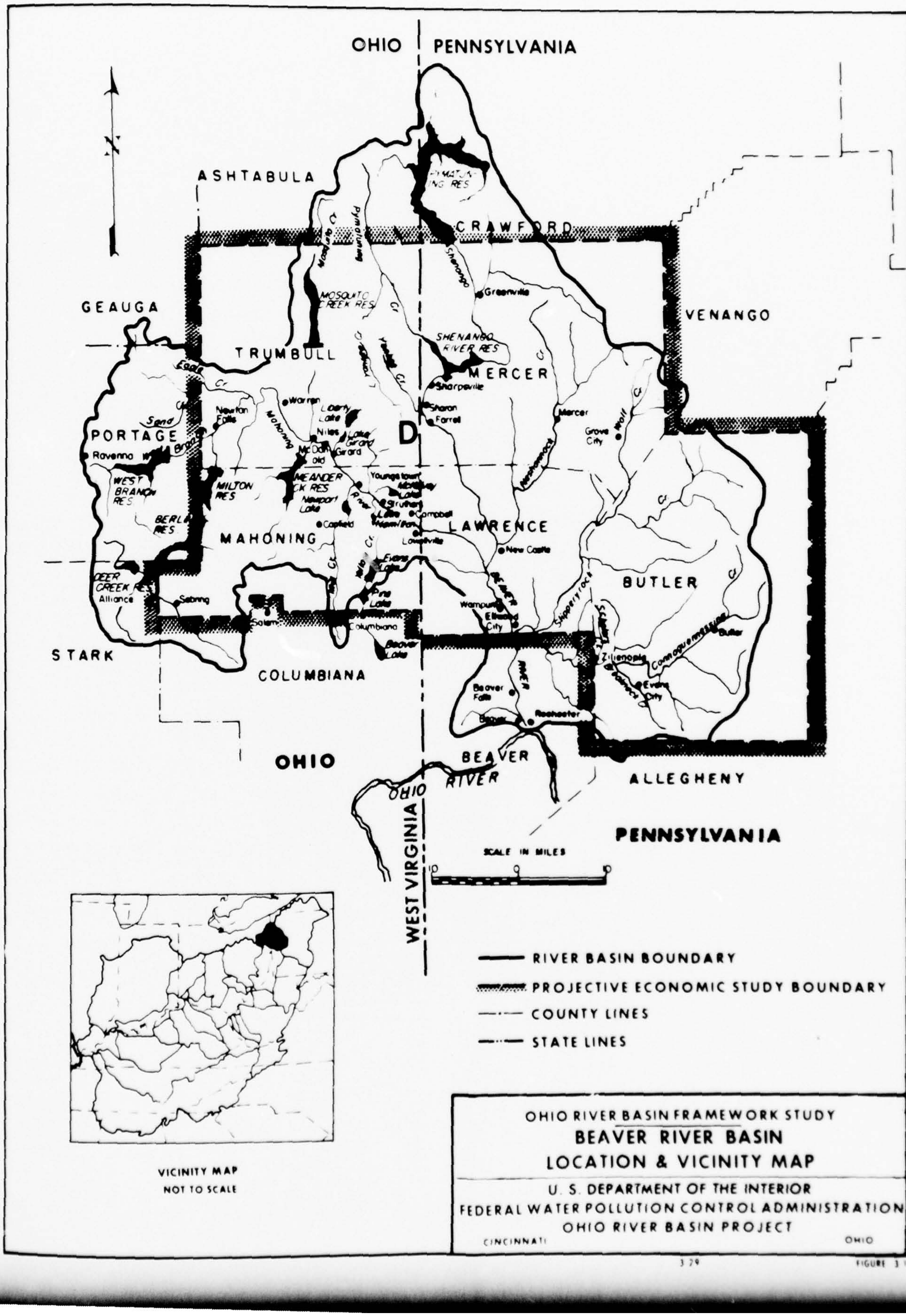
OHIO
PENNSYLVANIA
N
ASHTABULA
CRAWFORD
GEAUGA
TRUMBULL
MERCER
VENANGO
PORTAGE
MAHONING
LAWRENCE
BUTLER
STARK
COLUMBIANA
BEAVER
ALLEGHENY
OHIO
PENNSYLVANIA
WEST VIRGINIA
OHIO RIVER
PYMATUNING RES
MOSQUITO CREEK RES
SHENANGO RIVER RES
MILTON RES
MEANDER CK RES
WEST BRANCH RES
BERLIN RES
DEER CREEK RES
D
Greenville
Sharpsville
Sharon
Farrell
Mercer
Grove City
Warren
Niles
Girard
Youngstown
Campbell
Canfield
Lowellville
New Castle
Ravenna
Alliance
Sebring
Salem
Columbiana
Wampum
Ellwood City
Beaver Falls
Beaver
Rochester
Zelienople
Evans City
Butler
Newport Lake
Beaver Lake
SCALE IN MILES
10 0 10
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STUDY BOUNDARY
COUNTY LINES
STATE LINES
VICINITY MAP
NOT TO SCALE
OHIO RIVER BASIN FRAMEWORK STUDY
BEAVER RIVER BASIN
LOCATION & VICINITY MAP
U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 3-1

MUSKINGUM RIVER BASIN

Subbasin Area
No. 4

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I SUMMARY

Municipal and Industrial Water Supply Problems

The largest municipal water use occurs at Canton, Ohio, in the Tuscarawas River subbasin, at Newark, Ohio, in the Licking River subbasin and at Mansfield in the Walhonding River subbasin. Major industrial water use occurs in or about these major centers of population.

Projected needs at Canton starting in 1980 can probably be met from underground sources while Mansfield by 1980 should be looking to develop additional surface storage. Newark, presently using ground and surface sources which are only sufficient to meet present peak demands, is looking to abandonment of ground sources in favor of a new surface source.

Other communities that appear to be approaching safe limits of current supply facilities at the present are South Zanesville, Mount Vernon, Orrville and Wadsworth where ground water appears to be available in sufficient quantities to meet projected needs.

By 1980, Granville, Zanesville, Coshocton, Loudonville, Rittman, Wooster, Carrollton, Barberton and Heath presently using ground sources, and Ashland using combined ground and surface sources, can probably meet projected needs by expansion of ground water facilities. Also by 1980, Shelby will need to expand surface storage facilities to meet projected needs. Shelby, also has a possibility of a ground supply from bedrock located beneath the glacial drift. This source of supply should be explored.

Other communities that probably will encounter problems by 2000 are Millersburg, Louisville, Massillon, Minerva and North Canton.

Water Quality Control Problems

Major quality control problems in the basin occur in Nimishillen Creek below Canton and in the Rocky Fork of the Black Fork of the Mohican River below Mansfield where, even with secondary treatment of organic wastes, present critical low summer flows in these streams are not sufficient to assimilate residual organic wastes discharged to the stream without degradation of water quality.

Even assuming secondary treatment, stream conditions would be unsatisfactory because of small flows in headwater areas at the present in the Tuscarawas River below Barberton, Licking River below Newark, River Styx below Wadsworth and Rittman, Little Chippewa Creek below Orrville, Wills Creek below Cambridge, Stillwater Creek below Dennison-Uhrichsville, Black Fork of the Mohican River below Shelby, Killbuck Creek below Wooster, and Jerome Fork below Ashland. However, Wills Creek below Cambridge can be improved by releases from Salt Fork Reservoir when it is completed by the State.

In addition to problems in the stream resulting from residual organic wastes, a problem in the basin is the discharge of chlorides from industrial processes which adversely affect the entire length of the Tuscarawas and Muskingum Rivers.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Muskingum River Basin lies in the eastern part and entirely within the State of Ohio. It is bounded by the Scioto River drainage on the west, Lake Erie drainage area on the north, and the Ohio River, direct and minor tributary drainage, on the east and south. The Muskingum River is formed by the junction of the two principal tributaries, the Tuscarawas and Walhonding Rivers at Coshocton near the center of the basin. The tributaries of the Tuscarawas River rise near Barberton and the Walhonding River tributaries rise near Ashland in northern Ohio. The Muskingum flows south for about 110 miles where it enters the Ohio River at Marietta, Ohio, 172 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is 8,040 square miles comprising almost 20 percent of the land area of the State and covering all or part of the 27 counties listed in Table 1. The basin is roughly rectangular in shape, about 120 miles long in the north-south direction, and about 100 miles wide in the east-west direction. The basin extends north beyond Barberton, west beyond Mansfield and east beyond Canton (See Figure 4-1).

The main tributaries comprising the Muskingum River system are shown in Table 2.

Physical Features

The Muskingum River Basin is entirely within the Allegheny Plateau province. Portions of the basin were overrun by both Illinois and Wisconsin glaciation which covered the northern and western parts of the basin. The line of glaciation generally trends east to west from Canton to Loudonville, and thence almost directly south leaving the basin in Perry County. The parts of the basin that have been glaciated are characterized by gently rolling to flat topography. The unglaciated plateau is generally rough and well dissected. Broad valleys with prominent flood plains and terraces characterize the larger streams in the unglaciated area. The glaciers changed the drainage of every major stream in the basin and outwarh materials filled major stream valleys many miles past the ice fronts. The glacial deposits vary from thin and relatively impermeable till to thick permeable sand and gravel beds

There are no natural lakes in the basin. There are 14 major artificial reservoirs in the basin, 10 of which have conservation pools. The 14 reservoirs are flood control reservoirs, located in the Muskingum Watershed Conservancy District (MWCD) and were originally authorized for construction by the Public Works Administration on 20 February 1934, under the provisions of the National Industrial Recovery Act, in cooperation with the Muskingum Watershed Conservancy District of Ohio. The Flood Control Act of 28 June 1938 authorized reimbursement to the Conservancy District for actual expenditures made in acquiring lands, easements and rights-of-way for the reservoirs. The Flood Control Act of 11 August 1939 authorized inclusion of the reservoirs in the comprehensive flood control plan for the Ohio River Basin.1/ The recreation and flood control facilities of the reservoirs are operated by the Muskingum Watershed Conservancy District and the Corps of Engineers respectively. A number of other impoundments in the basin, have been constructed for recreation purposes. Several other reservoirs were constructed in conjunction with the Ohio and Erie Canal. This canal, now abandoned, traversed the basin along the Licking River and then followed the Muskingum River north from Dresden to Coshocton and along the Tuscarawas River to Akron.

Climate

The average annual precipitation in the basin varies from approximately 36 inches in the northern portion to approximately 41 inches in the southern portion.

Average minimum temperatures range from approximately 28°F in January in the northern part to 32°F in the southern part. Average maximum temperatures range from approximately 72°F in July in the northern part to approximately 74°F in the southern part.

The frost-free period varies from about 180 days in the southern portion of the basin to 150 days in the northern portion.

Principal Communities and Industries

Listed in Table 3 are some of the principal cities and their populations from 1910 to 1960.

Agriculture maintains an important position in the economy of the basin. Livestock raising, the dairy industry, and crop raising are the principal components of the agriculture industry.

Coal mining is important to the economy of the basin and crude oil production occurs throughout the basin. Salt and clay are mined in significant quantities in the northern portion of the basin.

1/ Corps of Engineers, Huntington District - Data Sheets-Authorized Projects - Volume 2, June 30, 1964.

Industry in the Canton-Massillon area consists of primary metal production, roller bearings, meat packing, engines, fabricated metals, rubber products, and vacuum cleaners. Mansfield industry produces primary metals, auto bodies, household laundry equipment, valves and steel pipe, heating equipment and automatic temperature controls. Newark manufacturing produces glassware, fiberglas products, meat products, automobile parts, household appliances and aluminum products. Zanesville industry produces meat products, glass containers, cement and tile, and electrical power and transmission line specialties. Barberton industry produces milk products, rubber products, alkalies and chlorine, and electrical supplies. Ashland industry produces rubber products, castings, pumps, and motor vehicles. Wooster industry produces paperboard, rubber products, bearings, truck and bus bodies, castings, and sheet metal fabricated products. A major industry in Cambridge is the manufacture of cash registers. Construction equipment, clay products, plastics, flat glass and metal products are produced in other communities of the basin.

III WATER RESOURCES

Surface Water Resources

Quantity

Surface flows in the basin have been influenced since 1938 by fourteen reservoirs in the Muskingum Watershed Conservancy District. The fourteen reservoirs are operated for flood control by the Corps of Engineers, although conservation pools are maintained in ten reservoirs primarily for recreation and wildlife purposes. The recreational activities of the reservoirs are operated by the Muskingum Watershed Conservancy District. In the lower basin on the Licking River, Dillon Reservoir, constructed by the Corps of Engineers, is operated primarily for flood control. Also in the lower basin, Salt Fork Reservoir, a State project that is under construction, will be operated primarily for water supply and flood control.

Impoundments constructed for water supply are Barberton Reservoir serving the city of Barberton, Clear Fork Reservoir serving the city of Mansfield, and Lake Dorothy serving an industrial water user. Knox Lake is a state reservoir constructed primarily for recreational use.

In addition to the impoundments described above, there are reservoirs which were constructed in the 1830's to serve as feeder lakes for the Ohio and Erie Canal. This canal, now abandoned, connected the Ohio River with Lake Erie. Starting near Portsmouth, Ohio, the canal followed the Scioto River to the southern boundary of Franklin County, then turned north-east paralleling Little Walnut Creek and crossed the divide into the Muskingum River Basin. In the basin, it followed generally the Licking, Muskingum and Tuscarawas Rivers to the divide near Akron and then followed the Cuyahoga River to Lake Erie. Buckeye Lake in the southern portion of the basin, one of the feeder lakes, is now operated by the State for recreation. The ten Portage Lakes in the northern part of the basin, also feeder lakes, are now operated for recreation by the State and along with Nimisila Reservoir constructed in 1942, serve as a source of water supply for industry.

The lower reach of the Muskingum River from Zanesville south to the Ohio River consists of a series of slack water nagivation pools constructed during the early 1800's to serve as part of the

canal system. This system was operated for some time by the Federal government, but was transferred to the State of Ohio by quit claim deed in October 1958 for rehabilitation and use for water supply and recreation.

Table 4 shows pertinent data regarding the aforementioned impoundments.

Generally, the streams in the northern part of the glaciated portion of the basin have higher sustained flows than those in the western part, due to the presence of relatively permeable glacial valley fill deposits in contrast to glacial valley fill deposits interbedded with clay layers which act as barriers to infiltation from the rivers. Tributary streams south and east of the limit of glaciation have little ground water storage and low sustained flows.

Table 5 shows stream data excerpted from hydrology data[1/] prepared by the Corps of Engineers.

Quality

Surface waters in the basin are primarily hard water of the calcium, magnesium bicarbonate or calcium, magnesium sulfate type with natural hardness ranging from 200 to 300 mg/l in the glaciated areas of the basin and from 200 to 400 mg/l in nonglaciated areas. During high flows, when a large part of the water is from surface runoff, concentrations of dissolved solids are less than during low flow, when the water is largely from ground sources. In addition to natural variations, changes in quality are often the result of acid and iron wastes from industrial sources and mine drainage, and brine discharges from industry. Acid and iron waste from coal mines is principally located in the southeastern portion of the basin while acid and iron waste from industry enters the streams draining the Canton, Massillon, Dover, Zanesville, Shelby, and Mansfield areas. Brine waste discharges resulting from manufacturing processes and salt mining operations in the headwaters of the Tuscarawas River in the Akron-Barberton area is a major pollutant altering natural surface water quality throughout the entire length of the Tuscarawas and Muskingum Rivers. Chloride content as high as 1,800 mg/l has been recorded at Newcomerstown and 5,000 mg/l below Massillon in the Tuscarawas River. Brines from oil well pumping are another source of chloride pollution which occurs primarily on tributary streams in the basin.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

Ground Water Resources

Quantity

Ground water resources are described by the U. S. Geological Survey[1] and the following discussion has been condensed from their report.

Glacial deposits cover the northern and western portions of the basin to a depth up to 300 feet thinning toward the central part of the basin. Outwash sand and gravel deposits are the best aquifers in the basin and occur in the valleys of the Tuscarawas, Walhonding, Licking, and Muskingum Rivers. Wells located in these aquifers in the Tuscarawas River valley are reported to yield as much as 2,000 gpm, while in the Walhonding River many of the wells yield more than 500 gpm. In the Licking River valley, individual wells drilled in the valley fill deposits do not yield as much water as those drilled in the outwash deposits where the yield is as much as 600 gpm. In the Muskingum River valley between Coshocton and Dresden, yield to individual wells is as much as 1,500 gpm, and south of Dresden yields as much as 500 gpm are reported.

The water bearing consolidated rocks underlying the western and west central part of the basin are sandstones and siltstones of the Mississippian system and generally yield less than 25 gpm to individual wells. In the northwestern and west central portions, the more productive wells range from 200 to 300 feet deep while in the southern portion up to 100 feet deep. In the northern portion of the basin, sandstone, shale, coal, limestone, and conglomerate strata of the Pottsville and Allegheny formations of the Pennsylvania systems are the most productive, yielding generally 5 to 20 gpm to individual wells at depths of from 90 to 425 feet.

In the southern part of the basin wells in the bedrock generally yield less than 40 gpm. In the Marietta area, where the Monongahela formation and Dunkard Group form the bedrock surface, well yields generally are less than 5 gpm and numerous dry holes have been reported.

Quality

Water from unconsolidated glacial deposits is hard and high in dissolved solids. This hardness is of the calcium and magnesium bicarbonate type ranging from 150 to 400 mg/l and total dissolved solid content from 200 to as high as 600 mg/l. Iron is generally present in undesirable quantities exceeding the 0.3 mg/l maximum suggested by the Public Health Service Drinking Water Standards.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

Water from bedrock formations is generally hard and high in dissolved solids and iron. Although hardness in the water from some wells sampled ranged as low as 20 mg/l, the high ranged up to almost 600 mg/l. Dissolved solids ranged from about 300 mg/l to over 1,000 mg/l.

IV THE ECONOMY

The Muskingum subarea of the Projective Economic Study is located in eastern Ohio encompassing the Muskingum River watershed and includes the 16 counties listed in Tables 6 and 7. To facilitate estimates of future water requirements and waste loads derived from the projected economy, the area is divided into three minor areas, F-1, F-2, and F-3, and correlated as nearly as possible with the intra-area hydrology. F-1 includes the six southern counties of the area, F-2 includes the six northwestern counties of the area, and F-3 includes the remaining four northeastern counties. The counties in each minor area are listed in Tables 6 and 7 and are shown on Figure 4-1, page 4-36.

Economic Profiles

Minor Area F-1

The population of minor area F-1 was 259,600 in 1960 with Newark, Cambridge, and Zanesville being the largest cities. Per capita personal income in this minor area was $1,572 in 1960 compared to $1,957 for the State of Ohio. All of the F-1 minor area with the exception of Licking County is within the region designated as Appalachia.

Manufacturing is the most important employment category and is characterized by a preponderance of establishments hiring fewer than 100 employees. The most significant change that took place between 1958 and 1964 was an upward shift from plants of the 100-249 employees size to those hiring 250-499 employees and the increase in small establishments. The most important industries are machinery (including electrical machinery), primary metals, motor vehicles and other durables. One thermal power generating plant with a capacity of 500 megawatts is located at Philo on the Muskingum River, south of Zanesville.

Agricultural employment stood at 6,200 in 1960, declined at an average annual rate of 7.3 percent from 1950 to 1960 and 190,000 acres were taken out of production between 1954 and 1959. Even so, the total value of farm products sold has remained at the 1959 level of $32 million. Livestock and livestock products accounted for 75 percent of the above figure. Less than 600 acres are under irrigation.

The area is a major producer of bituminous coal. In 1960, 6.4 million tons were extracted equaling 19 percent of total State production. Although crude oil production is not published on a county basis for Ohio, the number of producing wells that are drilled each year is available from State records. In 1960, 99 producing wells were drilled representing 23 percent of the total new wells in Ohio.

Minor Area F-2

Population in minor area F-2 in 1960 amounted to 324,700. There are five cities in the minor area having populations in excess of 10,000. Mansfield the largest, had a population slightly over 47,000. Holmes and Coshocton Counties are within the region designated as Appalachia. Per capita personal income equaled $1,749 in 1960, as compared to $1,957 for the State of Ohio.

Manufacturing establishments manifested a strong growth trend from 1958 to 1964. There has been not only an increase in number but also an increase in size. From 1958 to 1964, the number of plants hiring 100 workers or more increased from 77 to 94, Richland and Wayne Counties realizing the greatest increase. The most important industries are machinery (including electrical machinery), other nondurables, fabricated metals and other durables.

Two thermal power generating plants are located in minor area F-2. One plant is located at Conesville, south of Coshocton (capacity 433.5 megawatts) and the other is located at Orrville (capacity 38.5 megawatts). One pulp mill is located at Coshocton with a capacity of 120 tons per day.

Agricultural employment declined at an average annual rate of 3.8 percent between 1950 and 1960. Standard metropolitan statistical areas are located on either side of the area and furnish ready markets, particularly for dairy products. The total value of farm products sold in 1959 amounted to $64.8 million, $4.5 million more than in 1954, and dairy products and the remaining livestock products each accounted for 34.1 percent of the total. About 600 acres of the total 1.4 million acres of farm land were irrigated in 1959.

Bituminous coal and crude oil extraction were both significant in the area. In 1960, 1.9 million tons of coal were produced equaling 5.7 percent of total State production, and the area brought in 177 producing oil wells equaling 40.1 percent of the total new wells in the State.

Minor Area F-3

Minor area F-3 is the most industrialized area in the Muskingum subarea with a 1960 population of 456,000. Four larger cities were located in the minor area, Canton in Stark County being the largest with a population of 113,600, followed by Massillon in Stark County with a population of 31,200. The other two cities have populations of less than 15,000. Akron and Barberton, with populations of 290,351 and 33,805 respectfully, are not included in the Projective Economic Study. A portion of Akron and all of Barberton lies within the basin in adjacent Summit County. Stark County is designated a standard metropolitan statistical area and contains 74.6 percent of total F-3 minor area population. The remaining three counties are within the region designated as Appalachia. Per capita personal income averaged $1,928 in Stark County and $1,583 in the remaining counties, as compared with $1,957 for the State of Ohio.

There was a significant increase in the number of manufacturing establishments in the 500-999 and the 1,000-over employee categories, even though the total number of establishments employing 100 or more decreased by six plants. The most significant industries are machinery (including electrical machinery), primary metals, other durables and fabricated metals. Three small thermal power generating plants are located at Dover, Canton and Massillon in the area, with a total generating capacity of 39.3 megawatts.

Agriculture in this minor area showed a decline similar to the other minor areas. The total value of farm products sold in 1959 amounted to $28 million. Dairy products were the most important components comprising 38.4 percent of the total. Total acres under irrigation were 1,760, Stark County accounting for 1,600 acres of the total.

Bituminous coal production is of signal importance in the area. In 1960, eleven million tons were produced equaling 32.5 percent of total State production. Only 15 producing oil wells were drilled during 1960 representing 3.5 percent of total new wells in the State. One million tons of clay were also produced in minor area F-3 in 1960 equaling over 20 percent of total State extraction.

The Barberton-Akron complex in Summit County lies outside the study area, but the Muskingum drainage area boundary includes Barberton and a portion of the Akron metropolitan area. This is a rapidly growing industrial area. Between 1958 and 1964, 20 new manufacturing plants hiring over 100 employees had been established. The three most significant plants in 1964 in Barberton were an alkaline and chlorine plant hiring 2,200 workers, a rubber plant hiring 1,300 workers, and a fabricating metals plant hiring 2,900 workers.

Projected Population and Industrial Activity

Population, as shown in Table 6, is projected to increase from 1.0 million in 1960 to 1.3 million by 1980 and 2.0 million by 2020. These projections represent an increasing share of Ohio River Basin population from 5.5 percent in 1960 to 5.8 percent by 2020.

Agricultural output is projected to increase from $245 million in 1960 to $262 million by 1980. Manufacturing output is shown in Table 7 and is projected to increase from $3.3 billion in 1960 to $6.8 billion by 1980.

Table 7 shows 1960 output, employment and manufacturing employment. Projections to 1980, 2000, and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Muskingum subarea in the Projective Economic Study, eleven other counties have land area within the basin. These counties are listed in Table 8. Some of these counties have significant water using communities within the basin and projections of their water requirements and waste production are based on the projections of adjacent Projective Economic Study subareas.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

There are 108 central water supply systems in the Muskingum River Basin, serving a population of 649,755. The average daily water use is 86 mgd amounting to 133 gallons per capita daily use.

In the basin, about 57 percent of the water used for municipal supplies is from ground sources. The largest single water supply is Canton, using a ground source and accounting for approximately 22 percent of the total municipal water use. Most of the smaller communities under 2,500 have ground water sources, while intermediate sized communities in the 25,000 to 50,000 range use surface sources.

The present municipal and industrial water use is listed by county and totaled by economic subarea and the basin in Table 9.

In the eastern part of the upper basin, in minor area F-3, drained by the Tuscarawas River, the major growth will probably occur in Stark County in the Canton Standard Metropolitan Statistical Area (S.M.S.A.) which at the present accounts for over 80 percent of the municipal and industrial water use in the minor area.

In the western part of the upper basin, in minor area F-2, drained by the Walhonding River tributaries, major water use occurs in Richland County with Mansfield, the principal city, accounting for about 85 percent of the water use. Wooster accounts for about 50 percent of the total water use in Wayne County. A large per capita water use is recorded in Coshocton County. The city of Coshocton serves a population of 13,500 with 4 mgd for a per capita water use of nearly 300 gpcd.

In the lower basin, defined by minor area F-1, major water use occurs in Licking and Muskingum Counties. In Licking County, Newark accounts for 88 percent of the water use in the county and for over 50 percent of the municipal water use in minor area F-1. In Muskingum County, Zanesville accounts for almost 85 percent of the water use in the county and for over 17 percent of the municipal water use in the minor area.

Major municipal water use in other areas in the basin occurs in Summit County at Barberton accounting for over 80 percent of the water use in areas not included in the basin area defined by the Projective Economic Study.

Major industrial water use from surface sources occurs in Richland and Stark Counties at Mansfield and Canton respectively accounting for almost 53 percent of the total industrial water use in the basin.

Based on population increase and projected industrial activity, estimated water use will increase in the Muskingum River Basin as shown in Table 10. It is estimated that total municipal and industrial water requirements will quadruple by 2020. The major increases will probably occur in about the present centers of population and industry. In minor area F-2, total water use is projected to increase over four fold with the major increase probably occuring at Mansfield.

In minor areas F-1 and F-3, total water use is projected to increase about 3.75 times by 2020. In the former minor area, the major increase will probably occur around Newark and Zanesville while in the latter area, the major increase probably will occur in the Canton S.M.S.A. In other areas in the basin, water use is projected to increase almost four fold by 2020 with the major increase occuring at Barberton, part of the Akron S.M.S.A.

Water Supply Problems

The projected total water supply figures shown in Table 10, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to the need for future development of sources of water supply. Shown in Table 11 are problem areas with the approximate time of onset.

In minor area F-1, the total water use is projected to increase to 56 mgd by 1980, to 85 mgd by 2000 and to 127 mgd by 2020. Approximately 65 percent of the projected water use in this subarea will be supplied by central water supply systems. Newark is meeting present peak demands by augmenting its surface source with ground water located upstream from the city. A large industrial plant has installed conservation equipment which has reduced the demands on the city's supply. Several solutions can be offered for developing future sources. According to U. S. Geological Survey, sources, capable of major development exist in the glacial outwash deposits nearby and in the bedrock formations beneath.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Study.

TABLE 11

MUSKINGUM RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Granville	F-1		X		
Heath	F-1		X		
Newark	F-1		X		
South Zanesville	F-1	X			
Zanesville	F-1		X		
Ashland	F-2		X		
Loudonville	F-2		X		
Coshocton	F-2		X		
Millersburg	F-2			X	
Mount Vernon	F-2	X			
Mansfield	F-2		X		
Shelby	F-2		X		
Orrville	F-2	X			
Rittman	F-2		X		
Wooster	F-2		X		
Carrollton	F-3		X		
Canton	F-3		X		
Louisville	F-3			X	
Massillon	F-3			X	
Minerva	F-3			X	
North Canton	F-3			X	
Wadsworth	*	X			
Barberton	*		X		

*Not included in Projective Economic Study.

Surface sources could include upground reservoirs and allocation of water supply in a proposed multi-purpose reservoir in the area.

South Zanesville at the present time uses a ground water source and indications are that a shortage of supply exists, but development of additional wells will probably solve this problem. Cambridge, presently using a surface source, will draw its water supply from the Salt Creek Reservoir, that is being constructed by the State of Ohio.

Municipal water needs as projected will approach the dependable yields of presently developed sources at Granville, Zanesville and Heath by 1980. Ground water sources can probably be expanded at Zanesville, Granville and Heath to meet projected needs although an alternate solution at Heath could be connection to the city of Newark's water supply system.

In minor area F-2, the total water use is projected to 93.5 mgd by 1980, to 150 mgd by 2000 and to 216 mgd by 2020. At the present, about 55 percent of the municipal supply is from ground sources. Indications are that water supply systems in Coshocton, Mount Vernon and Orrville will have difficulty meeting peak demands from present sources, in the near future. Ground sources appear to be adequate and expansion of present well fields should meet foreseeable needs. By 1980, planning for additional water supply sources should be underway at Ashland, Loudonville, Mansfield, Shelby, Rittman and Wooster. Planning for additional sources should be underway by 2000 at Millersburg. Ashland using ground and surface sources and Loudonville, Coshocton, Millersburg, Mount Vernon, Orrville, Rittman and Wooster presently using ground water sources, are located where expansion of well fields can meet foreseeable needs. Mansfield and Shelby presently use surface sources. Ground water is reported to be available in the bedrock formations underlying these communities and probably should be investigated as a source of supply. Mansfield, prior to 1980, and Shelby, by 1980, should plan to develop additional supply. Since Mansfield and Shelby are in the headwaters region, additional surface water storage would have to be provided in upground reservoirs or reallocation of storage in existing reservoirs.

In minor area F-3, total water use is projected to increase to 93 mgd by 1980, 139 mgd by 2000 and 211 mgd by 2020. Planning for additional sources should be underway in Carrollton and Canton by 1980, in Massillon, Louisville, Minerva and North Canton by 2000. Canton, the largest water user in this minor area, obtains all of its supply from ground sources. The other communities obtain their supplies from ground ground sources. Based on available information regarding ground water resources in the area, both in the unconsolidated deposits and bedrock formations, all communities can likely meet future needs by expanding their well field systems.

Major water use in other areas in the basin occurs in Barberton and Wadsworth. Wadsworth should be planning now to increase its source of supply. Sufficient ground water appears to be available to supply foreseeable future needs. Barberton presently obtains about 70 percent of its supply from surface sources and the remainder from ground sources. By 1980, additional sources should be developed. Since Barberton is located in the headwaters region, additional surface water storage would probably have to be developed in upground reservoirs. Ground water supplies however, either in the glacial outwash deposits or in bedrock formations seem to be adequate to meet future needs.

Undoubtedly there are other smaller communities which will have water supply problems, but it is beyond the scope of this report to define these problem areas.

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

Present organic waste loads generated in the basin are shown in Table 12. In the lower portion of the Muskingum River Basin, defined generally by minor area F-1 boundaries, nearly 65 percent of the present organic waste loads generated are from municipal sources. Major sources of waste discharges are from Newark in Licking County, Zanesville in Muskingum County and Cambridge in Guernsey County. Major industrial organic waste discharge occurs near Zanesville. In the northwestern portion of the basin, defined generally by minor area F-2, nearly 55 percent of the organic wastes discharged are from industrial sources primarily in Coshocton and Wayne Counties. Major sources of municipal waste discharges are from Mansfield, Wooster and Ashland. In minor area F-3, whose boundaries generally define the northeastern portion of the basin, over 60 percent of the organic wastes discharged are from municipalities with the major discharges being from the Canton and Massillon areas. Major industrial organic waste is from the Canton area. In basin areas not included in the Projective Economic Study, major municipal and industrial organic waste discharges occur at Barberton.

Shown in Table 13 are the base and projected waste loads generated for the basin listed by minor areas and other areas in the basin. Waste loads are projected to increase to 3.5 times the present level by 2020 with minor area F-1 and other areas maintaining this average, minor area F-2 increasing to four times the present level and minor area F-3 increasing to three times the present level.

Water Quality Control Problems

Listed in Table 14 are the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures for pollution control. While needs in the following paragraphs are described as "present," they are actually based on 1960 data.

Major quality control problems in the basin are in Nimishillen Creek below Canton, and in the Rocky Fork of the Black Fork of the Mohican River below Mansfield where, even with secondary treatment, residual organic constituents discharged to the streams cause unsatisfactory stream conditions during periods of low flow.

TABLE 14

MUSKINGUM RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Tuscarawas River-Main Stem	Barberton	F-3	X			
Tuscarawas River-Main Stem	Massillon	F-3		X		
Little Chippewa Creek	Orrville	F-2 1/	X			
River Styx	Rittman	F-2 1/	X			
River Styx	Wadsworth	*	X			
Nimishillen Creek	Canton	F-3	X			
Stillwater Creek	Dennison-Uhrichsville	F-3	X			
Black Fork-Mohican River	Shelby	F-2	X			
Jerome Fork	Ashland	F-2	X			
Rocky Fork-Black Fork-Mohican River	Mansfield	F-2	X			
Kokosing River	Mount Vernon	F-2			X	
Killbuck Creek	Wooster	F-2	X			
Licking River	Newark	F-1		X		
Wills Creek	Cambridge	F-1	X			

*Not in Projective Economic Study.
1/ Located in an authorized PL-566 Watershed Project area.

The design flow in Nimishillen Creek is about 23 cfs, but flows on the order of 140 cfs are required at present, 210 cfs in 1980, 275 cfs in 2000 and 320 cfs in 2020. It does not appear that storage of the magnitude required to sustain these flows is available in the drainage area above Canton, so regulation of streamflow appears to be only a partial solution and advanced waste treatment methods will probably be required.

The design flow in the Rocky Fork of the Black Fork of the Mohican River below Mansfield is about 10 cfs. Flows in the order of

60 cfs are needed at the present, increasing to 85 cfs by 1980, 115 cfs by 2000 and 150 cfs by 2020 to maintain satisfactory conditions in the stream even after secondary treatment of organic wastes. Since Mansfield is in the headwaters region, storage of the magnitude required to sustain these flows is probably not available and flow regulation appears to be only a partial solution, and advanced waste treatment methods will probably be required.

Stream conditions in the Tuscarawas River below Barberton, where design flow is about 20 cfs, are unsatisfactory at the present. Flows in the order of 35 cfs are needed at present, increasing to 55 cfs by 1980, 85 cfs by 2000 and 120 cfs by 2020.

In the Tuscarawas River below Massillon, the design flow of about 68 cfs appears to be adequate to assimilate present residual organic wastes. By 1980, total flow needed in the stream will increase to 75 cfs, 100 cfs by 2000 and 125 cfs by 2020.

Stream conditions in the River Styx below Wadsworth and Rittman are unsatisfactory at present with small summer flows in the stream. Indications are that below Wadsworth flows on the order of 8 cfs are required at present, increasing to about 11 cfs by 1980, 15 cfs by 2000 and 20 cfs by 2020. If these flows are supplied, needs will be met at Rittman. Flow regulation does not appear to be the solution since storage does not appear to be available above these communities. The solution to the problem may be intensive treatment of the secondary plant effluent by "polishing" or holding ponds for release during high flow periods.

Other stream reaches where the summer flows are small are Little Chippewa Creek below Orrville, Wills Creek below Cambridge, the Stillwater Creek below Dennison-Uhrichsville and the Black Fork of the Mohican River below Shelby. At Orrville, Dennison-Uhrichsville, and Shelby, flows in the order of 10-12 cfs are required at present, increasing to 18 cfs by 1980, 25 cfs by 2000 and about 30 cfs by 2020. In Wills Creek below Cambridge, about 17 cfs is required at the present, 22 cfs by 1980, 30 cfs by 2000 and 40 cfs by 2020. As Orrville and Shelby are in headwater regions and storage does not appear to be available above these communities, flow regulation of the streams does not appear to be a complete solution. Here again more intensive treatment by "polishing" ponds or holding ponds for release during periods of higher flows may also be necessary. A solution for disposal of treated wastes at Dennison-Uhrichsville may be transmission to the Tuscarawas River, a stream with higher flows.

Additional studies may result in solution to the low flow requirements at Dennison-Uhrichsville and Cambridge by changes in operation procedures and/or reallocation of storage in upstream reservoir projects. Wills Creek below Cambridge can be improved by releases from Salt Fork Reservoir when completed by the State. The current study of the Muskingum Basin being conducted by the Corps of Engineers will consider reallocation of storage, changes in operations and additional reservoir sites.

Stream conditions are unsatisfactory at present in Killbuck Creek below Wooster and Jerome Fork below Ashland with summer design flows of about 8 cfs and 2 cfs respectively. Total flows in each of the streams in the order of 30 cfs are needed at present, 40 cfs in 1980, 55 cfs in 2000 and 70 cfs in 2020 to maintain satisfactory conditions.

In the Licking River below Newark, design low flow of about 40 cfs appears to be sufficient at the present to maintain satisfactory stream conditions. However, by 1980 needs will increase to 70 cfs, by 2000 to 90 cfs and by 2020 to 120 cfs.

In the Kokosing River below Mount Vernon, where design flow is about 18 cfs, indications are that toward the close of the study period after 2000, summer flows in the order of 35 cfs will be needed, increasing to 45 cfs by 2020.

There are undoubtedly other small tributaries adversely affected by discharge of residual wastes after secondary treatment, but it is beyond the scope of this report to define all of them.

Quality problems unrelated to population are heat, chloride pollution and mine drainage. Major sources of heat release to streams occur on the Muskingum River at Conesville, Philo and Beverly where plants with generating capacities of 433.5 megawatts, 500 megawatts and 876 megawatts respectively are located. Smaller power generating plants are installed at Barberton on the Tuscarawas River and Orrville on Little Chippewa Creek with capacities of 87 megawatts and 38.5 megawatts respectively. Heat discharges from these plants during periods of low flow have adverse effects on the streams in localized reaches during periods of low flow. Installation of cooling towers would alleviate this condition but would increase losses.

Chloride pollution resulting from industrial brine discharges is a problem in the headwaters of the Tuscarawas River affecting the entire length of the Tuscarawas and Muskingum Rivers. Production of sodium chloride (Na Cl) from rock salt deposits is accomplished in the Barberton-Rittman area by introducing fresh water into salt wells and pumping from the wells a saturated brine for processing. Chloride wastes can be disposed of by recovery of chlorides as marketable products or changes in processes to eliminate production of brines.

Another source of chloride pollution is brine discharge from oil well operations. Since oil is produced in most of the counties in the basin, many small streams in the basin are probably affected, but field investigation will be required to locate these areas. Injection of all salt water and other oil field wastes into deep disposal wells may be a solution to this problem.

Mining of bituminous coal occurs in nearly every county in the basin and results in acid drainage from the mines into adjacent streams. The most serious problem area is in the Moxahala Creek watershed.

TABLES

TABLE 1

MUSKINGUM RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Ohio	*	Ashland	81.1
"		Athens	0.8
"		Belmont	20.0
'	*	Carroll	80.0
"		Columbiana	9.4
"	*	Coshocton	100.0
"		Crawford	1.4
"		Fairfield	4.1
"	*	Guernsey	100.0
"	*	Harrison	72.3
"	*	Holmes	100.0
"	*	Knox	98.9
"	*	Licking	93.2
"		Medina	30.9
"		Monroe	9.2
"	*	Morgan	84.9
"		Morrow	33.9
"	*	Muskingum	100.0
"	*	Noble	55.7
"	*	Perry	41.0
"		Portage	0.4
"	*	Richland	88.8
"	*	Stark	86.6
"		Summit	43.0
"	*	Tuscarawas	100.0
"		Washington	33.9
"	*	Wayne	100.0

*Counties considered in economic projections of Muskingum River Basin.

TABLE 2

MUSKINGUM RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Muskingum River	8,040	110	0
Licking River	790	40	75
Wills Cree	850	65	99
Walhonding River	2,250	20	110
Tuscarawas River	2,590	125	110

TABLE 3

MUSKINGUM RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Canton	Stark	Ohio	50,217	87,091	104,906	108,401	116,912	113,631
Mansfield	Richland	"	20,768	27,824	33,525	37,154	43,564	47,325
Newark	Licking	"	25,404	26,718	30,596	31,487	34,275	41,790
Zanesville	Muskingum	"	28,026	29,569	36,440	37,500	40,517	39,077
Barberton	Summit	"	9,401	18,811	23,934	24,028	27,820	33,805
Massillon	Stark	"	13,879	17,428	26,400	26,644	29,594	31,236
Ashland	Ashland	"	6,795	9,249	11,141	12,453	14,287	17,419
Wooster	Wayne	"	6,136	8,204	10,742	11,543	14,005	17,046
Cambridge	Guernsey	"	11,327	13,104	16,129	15,044	14,739	14,562
New Philadelphia	Tuscarawas	"	8,542	10,718	12,365	12,328	12,948	14,241
Mount Vernon	Knox	"	9,087	9,237	9,370	10,122	12,185	13,284
Coshocton	Coshocton	"	9,603	10,847	10,908	11,509	11,675	13,106
Dover	Tuscarawas	"	6,621	8,101	9,716	9,691	9,852	11,300
Wadsworth	Medina	"	3,073	4,742	5,930	6,495	7,966	10,635
Shelby	Richland	"	4,903	5,578	6,198	6,643	7,971	9,106

TABLE 4

MUSKINGUM RIVER BASIN

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Pool Area (acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Dillon	F, R	1,325	261,000		12,700
Salt Fork 4/	F, W, R	3,000		42,000	
Barberton	W	200		670	
Buckeye Lake	R	2,853			19,940
Clear Fork	W, R (L)	997			10,760
Lake Dorothy	W, R (L)	100			1,058
Knox Lake	R	495			
Nimisila	W	811		9,500	
Chippewa Lake	R	332			
Portage Lakes 1/	W (R)	1,198			
Atwood 3/	F, R	1,540	26,100		23,600
Beach City 3/	F, R	420	70,000		1,700
Bolivar 3/	F	2/	149,600		
Charles Mill 3/	F, R	1,350	80,600		7,400
Clendening 3/	F, R	1,800	27,500		26,500
Dover 3/	F	2/	202,000		
Leesville 3/	F, R	1,000	17,900		19,500
Mohawk 3/	F	2/	285,000		
Mohicanville 3/	F	2/	102,000		
Piedmont 3/	F, R	2,270	31,400		33,600
Pleasant Hill 3/	F, R	850	74,200		13,500
Senecaville 3/	F, R	3,550	45,000		43,500
Tappan 3/	F, R	2,350	26,500		35,100
Wills Creek 3/	F, R	900	190,000		6,000

1/ Consists of 10 lakes, interconnected, with total area shown.
2/ No conservation pool.
3/ Muskingum Conservancy District Reservoirs. M.C.D. operates recreation facilities and the Corps of Engineers operates the flood control facilities.
4/ Under construction by State.

F - Flood Protection
W - Water Supply
R - Recreation - (L) Limited

TABLE 5

MUSKINGUM RIVER BASIN

Flow Data

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min.3/ Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg.3/ 1 in 10 Yr Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Muskingum River						
Coshocton, Ohio 1/	4,842	4,855	342	78,700	464	337
Dresden, Ohio 2/	5,982	6,173	335	100,000	498	375
Zanesville, Ohio 1/	6,840	6,926	420	80,900	550	400
McConnellsville, Ohio 2/	7,411	7,282	218	126,000	565	397
Tuscarawas River						
Clinton, Ohio	165	141	10	2,700	18	10
Dover, Ohio	1,398	1,375	2.3	26,400	159	
Newcomerstown, Ohio	2,436	2,422	120	46,800	210	
Mohican River						
Greer, Ohio	942	879	50(est.)	17,70C		
Licking River						
Toboso, Ohio	672	672	34	49,800	50	40
Walhonding River						
Nellie, Ohio	1,502	1,457	3.3	43,800		
Nimishillen Creek						
North Industry, Ohio	175	166	3.6	8,600	23	10
Sandy Creek						
Sandyville, Ohio	481	495	26	14,200	61	38
Jerome Fork						
Jeromeville, Ohio	120	97	1.5	3,720	2.4	1.8

1/ Low flow regulated by Bolivar, Leesville, Atwood, Dover, Beech City, Piedmont, Clendening, Tappan, Charles Mill, Pleasant Hill, Mohicanville and Mohawk Reservoirs since 1936.
2/ Low flow regulated by Reservoirs listed in 1/ plus Senecaville and Mills Creek since 1938.
3/ Natural flow.

TABLE 6

MUSKINGUM RIVER BASIN

Economic Subarea F
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation F-1									
Ohio	Guernsey	38,600	14,600						
"	Licking	90,200	47,600						
"	Morgan	12,700	0						
"	Muskingum	79,200	39,100						
"	Noble	11,000	0						
"	Perry	27,900	7,500						
	Subtotal	259,600	108,800	342,000		438,000		535,000	
Area Designation F-2									
Ohio	Ashland	38,800	20,000						
"	Coshocton	32,200	13,100						
"	Holmes	21,600	3,100						
"	Knox	38,800	13,300						
"	Richland	117,800	78,700						
"	Wayne	75,500	29,000						
	Subtotal	324,700	157,200	434,000		558,000		662,000	
Area Designation F-3									
Ohio	Carroll	20,900	4,500						
"	Harrison	18,000	3,300						
"	Stark	340,300	244,000						
"	Tuscarawas	76,800	40,200						
	Subtotal	456,000	292,000	550,070		666,470		823,000	
Total Subarea F		1,040,300	558,000	1,326,070	873,000	1,662,470	1,199,000	2,020,000	1,589,000

TABLE 7

MUSKINGUM RIVER BASIN

Economic Subarea F
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation F-1													
Ohio	Guernsey	12,300	3,700										
"	Licking	31,500	11,300										
"	Morgan	4,000	800										
"	Muskingum	27,100	9,400										
"	Noble	3,300	700										
"	Perry	8,400	3,200										
	Subtotal	86,600	29,100	651.7	137	118	205	186	145	388	254	185	755
Area Designation F-2													
Ohio	Ashland	14,800	5,800										
"	Coshocton	11,400	4,300										
"	Holmes	6,900	1,400										
"	Knox	13,500	4,300										
"	Richland	43,200	19,000										
"	Wayne	27,400	9,300										
	Subtotal	117,200	44,100	1051.7	136	145	221	176	184	433	226	214	725
Area Designation F-3													
Ohio	Carroll	6,900	2,700										
"	Harrison	6,000	1,500										
"	Stark	120,900	53,500										
"	Tuscarawas	26,300	10,700										
	Subtotal	160,100	68,400	1598.1	124	124	197	155	148	352	199	175	621
Total Subarea F		363,900	141,600	3301.5	131	130	207	169	158	383	220	189	681

*In millions of 1960 dollars.
**1960 = 100

TABLE 8

MUSKINGUM RIVER BASIN

Cou ties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Ohio	Athens	E-1	Upper Ohio
"	Belmont	E-2	Upper Ohio
"	Columbiana	E-2	Upper Ohio
"	Crawford	*	
"	Fairfield	I-1	Scioto
"	Medina	*	
"	Monroe	E-1	Upper Ohic
"	Morrow	I-2	Scioto
"	Portage	*	
"	Summit	*	
"	Washington	E-1	Upper Ohio

* - Not included in Projective Economic Study of Ohio River Basin.

TABLE 9

MUSKINGUM RIVER BASIN

Base Municipal and Industrial Water Use

State	County	No. of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation F-1											
Ohio	Guernsey	5	20,050	3,400	16,650	3.802	0.622	3.180	190	Wells, Wills Creek, Impoundments	0.5
"	Licking	9	59,325	17,325	42,000	13.602	1.602	12.000	229	Wells, North Fork Licking River	3.0
"	Morgan	4	4,215	4,215		0.627	0.627		149	Wells	0.2
"	Muskingum	8	50,140	47,640	2,500	4.945	4.745	0.200	99	Wells and Reservoir	7.0
"	Noble	0									
"	Perry	2	3,830	530	3,300	0.300	0.050	0.250	78	Wells and Lake	0.2
	Subtotal	28	137,560	73,110	64,450	23.276	7.646	15.630	169		10.9
Area Designation F-2											
Ohio	Ashland	4	21,460	4,060	17,400	2.428	0.348	2.080*	113	Wells, Lang Creek, Jerome Fork	0.2
"	Coshocton	3	15,570	15,570		4.260	4.260		274	Wells	1.8
"	Holmes	4	4,530	4,530		0.395	0.395		87	Wells	0.3
"	Knox	5	21,665	21,665		2.785	2.785		129	Wells	1.0
"	Richland	6	66,815	5,815	61,000	8.680	0.380	8.300	130	Wells, Clear Fork, Black Creek	17.8
"	Wayne	12	41,315	40,290	1,025	4.532	4.472	0.060	110	Spring, Wells, Muddy Fork Creek	7.0
	Subtotal	34	171,355	91,930	79,425	23.080	12.640	10.440	135		28.1
Area Designation F-3											
Ohio	Carroll	2	4,300	4,300		0.360	0.360		84	Wells	0.5
"	Harrison	5	3,295	3,295		0.228	0.228		69	Wells	0.1
"	Stark	15	226,690	181,690	45,000	26.357	23.107	3.250*	116	Wells and Newman Creek	20.0
"	Tuscarawas	14	51,200	39,700	11,500	5.542	4.512	1.030	108	Wells, Stillwater Creek and Reservoir	4.0
	Subtotal	36	285,485	228,985	56,500	32.487	28.207	4.280	114		24.6
Other Areas in Basin											
Ohio	Belmont	1	540	540		0.048	0.048		89	Wells	0
"	Medina	6	17,920	17,920		1.257	1.257		87	Wells	0.7
"	Summit	1	35,000		35,000	5.770		5.770	165	Wolf Creek and Wells	5.0
"	Washington	2	1,895	1,895		0.097	0.097		51	Wells	2.5
	Subtotal	10	55,355	20,355	35,000	7.172	1.402	5.770	135		8.2
	TOTAL	108	649,755	414,380	235,375	86.015	49.895	36.120	133		71.8

TABLE 10

MUSKINGUM RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation F-1												
From Central Supplies	137,560	169	23.3	222,800	173	38.5	312,000	180	56.0	415,000	183	76.0
Industrial			10.9			17.5			29.0			51.0
Subtotal			34.2			56.0			85.0			127.0
Area Designation F-2												
From Central Supplies	171,355	135	23.1	283,700	148	42.0	396,000	159	63.0	512,000	164	84.0
Industrial			28.1			51.5			87.0			132.0
Subtotal			51.2			93.5			150.0			216.0
Area Designation F-3												
From Central Supplies	285,485	114	32.4	425,400	126	53.6	560,000	138	77.3	754,000	150	113.0
Industrial			24.6			39.4			61.7			98.0
Subtotal			57.0			93.0			139.0			211.0
Other Areas in Basin												
From Central Supplies	55,355	135	7.2	84,200	149	12.5	114,000	160	18.2	153,000	165	25.2
Industrial			8.2			13.5			20.8			32.8
Subtotal			15.4			26.0			39.0			58.0
Muskingum River Basin												
From Central Supplies Total	649,755	133	86.0	1,016,100	144	146.6	1,382,000	155	214.5	1,834,000	163	298.2
Industrial Total			71.8			121.9			198.5			313.8
GRAND TOTAL			157.8			268.5			413.0			612.0

TABLE 12

MUSKINGUM RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation F-1						
Ohio	Guernsey	3	17,585	Wills and Leatherwood Creek	17,585	1,000
"	Licking	5	51,520	S. and N. Fk.Licking River, Raccoon Creek, Licking River	51,520	7,000
"	Morgan	2	3,235	Muskingum River	3,235	800
"	Muskingum	4	44,095	Crooked and Wills Creek, Muskingum River	44,095	58,000
"	Noble	0	0		0	0
"	Perry	1	2,960	Moxahala Creek	2,960	1,700
	Subtotal	15	119,395		119,395	68,500
Area Designation F-2						
Ohio	Ashland	4	21,315	Lake and Black Fork of Mohican River, Mahoning River	21,315	2,000
"	Coshocton	2	14,580	Muskingum and Tuscarawas River	14,580	100,000
"	Holmes	2	3,965	Killbuck Creek	3,965	2,500
"	Knox	5	17,850	Kokosing, North Fork, Licking River, Jelloway Creek	17,850	3,500
"	Richland	6	60,050	Clear Fork, Rocky Fork, Black Fork, Muskingum River	60,050	2,000
"	Wayne	9	36,165	Killbuck Crk., Newman Crk., Chippewa Crk., River Styx	36,165	65,000
	Subtotal	28	153,925		153,925	175,000
Area Designation F-3						
Ohio	Carroll	1	2,785	Indian Creek	2,785	1,000
"	Harrison	1	505	Stillwater Creek	505	0
"	Stark	13	200,375	Sugar Crk., Nimishillen Crk., Sandy Crk., Tuscarawas River	200,375	131,750
"	Tuscarawas	8	47,315	Stillwater Crk.,Tuscarawas River	47,315	18,100
	Subtotal	23	250,980		250,980	150,850
Other Areas in Basin						
Ohio	Medina	4	12,540	Chippewa Crk.,Camel Crk., River Styx	12,540	3,000
"	Summit	1	33,805	Tuscarawas River	33,805	25,000
"	Washington	2	1,975	Muskingum River	1,975	500
	Subtotal	7	48,320		48,320	28,500
	TOTAL	73	572,620		572,620	422,850

*NOT to be interpreted as waste loads to the stream.

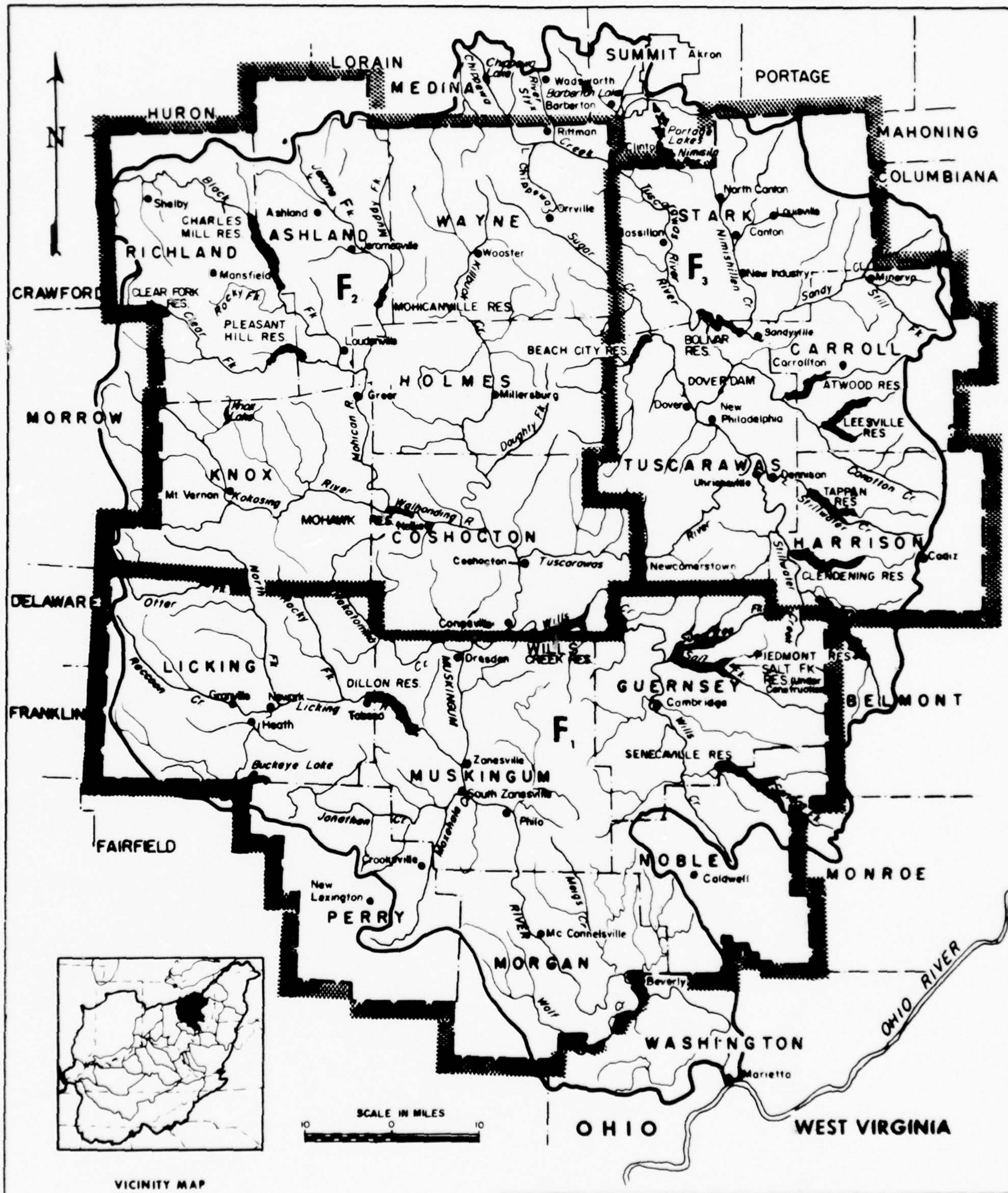
TABLE 13

MUSKINGUM RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation F-1				
Domestic and Commercial	119,395	193,400	271,000	361,000
Industrial	68,500	111,000	182,000	322,000
Subtotal	187,895	304,400	453,000	683,000
Area Designation F-2				
Domestic and Commercial	153,925	254,000	356,000	460,000
Industrial	175,000	320,200	541,000	822,000
Subtotal	328,925	574,200	897,000	1,282,000
Area Designation F-3				
Domestic and Commercial	250,980	374,000	492,000	663,000
Industrial	150,850	241,400	377,000	600,000
Subtotal	401,830	615,400	869,000	1,263,000
Other Areas in Basin				
Domestic and Commercial	48,320	79,700	112,000	144,000
Industrial	28,500	52,200	88,000	134,000
Subtotal	76,820	131,900	200,000	278,000
Muskingum River Basin				
Domestic and Commercial Total	572,620	901,100	1,231,000	1,628,000
Industrial Total	422,850	724,800	1,188,000	1,878,000
GRAND TOTAL	995,470	1,625,900	2,419,000	3,506,000

interpreted as waste loads to the stream.



VICINITY MAP
NOT TO SCALE

- RIVER BASIN BOUNDARY
- PROJECTIVE ECONOMIC STUDY BOUNDARY
- COUNTY LINES
- STATE LINES

OHIO RIVER BASIN FRAMEWORK STUDY

MUSKINGUM RIVER BASIN
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 4-1

KANAWHA-LITTLE KANAWHA RIVER BASINS

Subbasin Area
No. 5

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I SUMMARY

Kanawha River Basin

Municipal and Industrial Water Supply Problems

The major municipal and industrial water use occurs in the reach of the Kanawha River in the vicinity of Charleston, West Virginia. Surface water is used to satisfy needs and ample supplies are available to meet future needs throughout the study period.

Problems in supply have been reported to exist at Wytheville, Pearisburg, and Narrows, Virginia, and Boone, North Carolina. There are ample surface sources of supply in the vicinity of these communities which can be developed to meet future needs. Beckley, West Virginia, is presently planning to develop additional sources of supply.

Water Quality Control Problems

The major problem area in the Kanawha River Basin occurs in the Kanawha River at and below the Charleston, West Virginia, industrial complex. The present critical problem area is the reach from mile point 56 to mile point 31.3 at the Winfield Dam. Even assuming a high degree of treatment of organic wastes, present critical low summer flows in the lower portion of the Kanawha River are not sufficient to assimilate the residual organic loads discharged to the stream without serious degradation of water quality. In addition to the organic portion of the industrial waste loads discharged to this reach of river, other related problems are toxicity, color and taste, and/or odor properties. Under present conditions of treatment, the situation is critical at the present time and will continue to worsen under projected population growth and industrial activity.

Other reaches of streams in the basin where conditions are unsatisfactory at present during low flow periods are the East Fork of the Greenbrier River below Durbin, West Virginia, and the Bluestone River below Bluefield, Virginia. By 1980, due to projected population growth and industrial activity, stream conditions at design low flows will be unsatisfactory in Peak Creek below Pulaski, Virginia, Buffalo Creek below West Jefferson, North Carolina, and Chestnut Creek below Galax, Virginia, and by 2000 in Piney Creek below Beckley, West Virginia.

Little Kanawha River Basin

Municipal and Industrial Water Supply Problems

The major water use in the basin is projected in the lower reach of the river where ample supply of water will be available from the pool in the lower Kanawha River formed by Belleville Dam on the Ohio River.

In the upper portion of the basin, the community of Spencer is presently experiencing a shortage of supply during the drier months. Present and future needs can be met by provision of local impoundments.

Water Quality Control Problems

There is an existing water quality problem in the reach of the Little Kanawha River in pool from navigation dams on the Ohio River. Industrial waste discharges coupled with the lower water quality of the Ohio River at this point and the embayment action of this backwater pool result in degradation of the Little Kanawha River over the last 3.8 miles of its length at Parkersburg.

The new high-level Belleville Dam on the Ohio River is to be completed by 1968, and this will extend the backwater area to about mile point 22. The contributions of industrial wastes, the relatively low flow of the Little Kanawha River, and its very low gradient throughout its lower reaches will result in a problem in this extended backwater area.

II DESCRIPTION OF STUDY AREA

Kanawha River Basin

Location and Boundaries

The Kanawha River Basin spans the entire width of the southern part of the State of West Virginia, includes the west-central portion of the Commonwealth of Virginia, and the northwestern part of the State of North Carolina. It is bounded on the north by the Little Kanawha and Monongahela River Basins, on the east by the Potomac, James, and Roanoke River Basins, on the south by the Pee Dee River Basin, and on the west by the Tennessee, Big Sandy, and Guyandotte River Basins. The total drainage area of the Kanawha River Basin is 12,300 square miles, 8,450 of which are in West Virginia, 3,080 in Virginia, and 770 in North Carolina and covers all or part of the 35 counties listed in Table 1a.

The Kanawha River is formed by the confluence of the New and Gauley Rivers at Gauley Bridge, West Virginia. From the point of origin it flows northwesterly for 95 miles to its junction with the Ohio River at Point Pleasant, West Virginia. The confluence of the Kanawha and the Ohio Rivers is 266 river miles below Pittsburgh, Pennsylvania. The main tributaries comprising the Kanawha River system are shown in Table 2a.

Physical Features

The Kanawha River Basin is located in the Kanawha section of the Appalachian Plateaus physiographic province, the Tennessee section of the Valley and Ridge province, and the southern section of the Blue Ridge province. The entire basin is mountainous in character, although the upper and lower portions comprise two contrasting types of topography. Rounded hills and wide valleys characterize the Appalachian Plateaus province of the lower basin, and high mountains and deep gorges characterize the Blue Ridge province of the upper basin. The elevations of the basin range from a high of approximately 5,000 feet in the Blue Ridge Mountains of North Carolina to 538 feet at the mouth of the Kanawha River, giving a maximum relief of about 4,500 feet.

The bedrock of the Kanawha River Basin in West Virginia is composed of consolidated rock of sedimentary origin. These rocks are a part of the Appalachian Basin strata. In the extreme eastern and southern sections of the basin in West Virginia, major folding accompanied by faulting has resulted in anticlinal mountains trending southwest-northeast and the exposure of considerably older rocks. This area is known as the Valley and Ridge Province.

The geologic materials of the Blue Ridge Province in Virginia and North Carolina include metamorphic and intrusive igneous rocks containing a fairly sizable suite of minerals many of which have given rise to commercial mining. A considerable number of faults exist in the area in contrast to the relative absence of faulting in the West Virginia portion of the basin.

Climate

The climate throughout most of the Kanawha-Little Kanawha area is continental in character and varies over a wide range. Seasons are of near equal length. Winters are moderate to severe, but summers are warm to mild. Topography considerably modifies normal control of the climate by latitude. Consequently, existing topographic differences cause marked variations in precipitation and temperature between the mountainous areas and the hilly plateau lands.

Mean annual precipitation ranges from about 35-45 inches at lower elevations to approximately 55 inches in the upper reaches. Approximately 10 percent of the precipitation falls as snow. High flows characteristically occur in the winter and spring, and low flows occur during the summer and fall. Mean annual temperature ranges from about 48°F in upper areas to approximately 57°F in lower portions of the basin. The average length of frost-free periods ranges from 160 days at high altitudes to 197 days at Charleston, West Virginia.

Principal Communities and Industries

Agriculture, manufacturing, and mining each hold an important position in the economy of the basin. Hay is the principal agricultural enterprise and the bulk of the rural economy is related to livestock production. Mining output continues to be important with coal the principal product extracted. However, the relative importance of manufacturing increases annually. Manufacturing is especially strong in the Charleston, West Virginia area.

Principal communities and their growth patterns from 1910 to 1960 are shown in Table 3a.

Little Kanawha River Basin

Location and Boundaries

The Little Kanawha River Basin embraces 2,309 square miles of west-central West Virginia, lying entirely within the State, and comprises nearly 10 percent of the area of the State. The basin is approximately 80 miles in length, and its maximum width is about 50 miles. It is bounded on the south by the Kanawha Basin, on the west by the Ohio River, on the north by the Middle Island Creek Basin, and on the east by the Monongahela Basin. The basin contains all or part of the 12 counties shown in Table 1b. The Little Kanawha River heads in southwestern Upshur County and extends approximately 165 miles to the northwest to its mouth at Parkersburg, West Virginia, 185 river miles below Pittsburgh, Pennsylvania. From the headwaters to a point 44 miles downstream, the river has a fall of approximately 29.5 feet per mile. The rate of fall for the remaining 121 miles is only about 1.5 feet per mile. The pertinent data regarding the Little Kanawha River drainage system are shown in Table 2b.

Physical Features

The Little Kanawha River Basin is located in the Kanawha section of the Appalachian Plateaus physiographic province. The basin exhibits the steep slopes, sinuous ridges, and fine dissection characteristic of this section. Flat land is mostly absent except along the lower reach of the river where broad flood plains and terraces make up the topography. Parkersburg, West Virginia, is located on the flat land near the confluence of the Little Kanawha and Ohio Rivers. The topography of the basin is rugged throughout with elevations in the headwaters reaching approximately 2,200 feet. The normal pool elevation at the mouth of the basin is 572 feet, giving a total relief of about 1,630 feet.

Rock strata underlying the basin are composed of consolidated rocks of sedimentary origin. The rocks are nearly flat lying, except for gentle warps of local extent and outcrops in a general older-to-younger pattern from east to west. Soil erosion has been

moderate to severe over much of the area, particularly where the slopes have been deprived of adequate vegetative cover as a result of lumbering, farming, and mining activities. About 60 percent of the basin is forest land. Extensive deposits of unconsolidated alluvium occur along the lower Little Kanawha River valley and along the Ohio River.

Climate

The climate in the Little Kanawha River Basin is similar to that for the Kanawha River Basin and is described in that portion of this study.

Principal Communities and Industries

The major sources of income in the basin are derived from agriculture, manufacturing, and mining. Also, with 60 percent of the area in commercial forest land, timber extraction is important to the economy of the basin. Nearly 90 percent of farm production is livestock and livestock products. Coal is the most valuable mineral resource in the basin, but most of the increased economic activity in the mining industry comes from an expansion of gas and oil production. Most of the industrial and commercial activity is in Wood County with Parkersburg, located on the main stem Ohio River, as the principal manufacturing community.

Principal communities and their population patterns from 1910 to 1960 are shown in Table 3b.

III WATER RESOURCES

Kanawha River Basin

Surface Water Resources

Quantity

Surface flows in the basin are greatly affected by a number of single and multiple-purpose reservoirs as well as by three navigation structures on the Kanawha River. Table 4 shows pertinent data for the larger of these reservoirs.

The existing Bluestone, Summersville, and Sutton Reservoirs and the proposed Blue Ridge Reservoir are of major importance. The three existing reservoirs constructed by the Corps of Engineers have a total storage of 1,252,100 acre-feet for flood control and 260,000 acre-feet for other purposes such as low flow regulation.

Of the Kanawha basin's entire 12,300 square mile drainage area, the present Bluestone, Summersville, and Sutton Reservoirs control a total of 5,905 square miles of drainage area.

The Byllesby, Hawks Nest, Little River, and Buck Reservoirs are privately owned reservoirs for the purpose of producing hydroelectric power. The Gatewood and Beckley Water Company Reservoirs are used as a source of water supply, and the Stevens Branch, Plum Orchard, Sherwood, and Moncove Lakes are primarily for recreational purposes.

The main stem Kanawha River is navigable from its mouth to mile point 91. The three dams which maintain the navigation pools are the Winfield Dam at mile point 31, the Marmet Dam at mile point 67.7, and the London Dam at mile point 82.8. Each of these three dams also has hydroelectric power generating facilities. Gallipolis Locks and Dam, located on the Ohio River, is also considered a necessary part of the Kanawha Navigation System.

The dry weather flow of streams in the Kanawha River basin ranges widely and reflects the varying geologic and hydrologic controls within the basin. Gaging stations in the upper New River basin above Galax, Virginia show some of the highest sustained flows in the Ohio River basin. (.54 to .78 cfs per square mile exceeded 90 percent of the time.) This is due to a combination of abundant precipitation along the Blue Ridge and the relatively permeable igneous and metamorphic rocks with high infiltation capacities that underlie the area. The Greenbrier River, underlain by limestones, shales and sandstones of varying permeability has a low-flow index of 0.11 cfs per square mile at its downstream station. The Gauley River, underlain by sandstones of the Pottsville formation, has a low-flow index of 0.10 cfs/sq. mi. at the Summersville gage in contrast to an index of 0.007 cfs/sq. mi. for the Pocatalico River at Sissonville. Most of the Pocatalico drainage area is underlain by shales and sandstones of the Monongahela Formation, which is a relatively poor aquifer.

Quality

Natural quality of surface waters in the Kanawha River Basin is generally good, being soft to moderately hard waters of the calcium and magnesium bicarbonate or calcium sulfate type, depending on locality, and with low dissolved mineral content. Total hardness, expressed as calcium carbonate, averages less than 50 mg/l during periods of high to medium flows, and dissolved solids average about the same. During periods of low flow hardness and dissolved solid content generally increase due to ground water discharges which make up an appreciable amount of the flow.

Changes in quality are affected in reaches of various streams in the basin by discharges of domestic and industrial wastes and by discharges from coal mines.

The main stem of the Kanawha River from about mile point 69 to its mouth is degraded by municipal and industrial wastes which results in a range in stream oxygen conditions from some degradation to septic conditions. The present critical reach is from just below Charleston to the Winfield Dam. During times of low streamflow, this area experiences periods of zero dissolved oxygen content.

Although a number of small streams contain varying amounts of acid mine drainage, because of the natural alkalinity of the streams, the effect of this pollutant is generally significant only in that it affects the hardness and dissolved solids content.

Waters of the Coal River and Little Coal River, tributary to the Coal River, are moderately hard to very hard, calcium magnesium sulfate type waters due to sulfate from coal mining areas. Mineralization is also much higher in this subbasin as compared to other areas in the basin.

Ground Water Resources

Quantity

The Kanawha River Basin is underlain by consolidated rocks ranging from Precambrian to Permian in age. Ground water supplies adequate for domestic needs (20 gpm or less) are available in most areas. Larger supplies for industrial and public supply needs (200 gpm or more) are available in some areas.

The principal bedrock aquifers are coarse-grained sandstones and conglomerate of the Pottsville and Allegheny formations in the central part of the basin. Yields of as much as 600 gpm are obtained from individual wells.

Other good potential sources of ground water are metamorphosed gneiss, schist, phyllite, and conglomerate in the headwaters of the basin where yields of more than 70 gpm are obtained and weathered carbonate rocks of the central part of the basin where some springs yield as much as 500 gpm.

Unconsolidated alluvium along the Kanawha River valley from Charleston to Point Pleasant is as much as 70 feet thick and is a good potential source of ground water. Yields of as much as 150 gpm are obtained from standard vertical screened wells that tap sand and gravel aquifers in the alluvium.

Quality

Ground water from the Pottsville and Allegheny formations, at depths of less than 300 feet in their outcrop areas, is usually soft or only moderately hard and only slightly mineralized and is suitable for domestic and industrial purposes with little or no treatment. However, in places where anticlinal structures are eroded, as at Charleston, the shallow ground water is more mineralized.

The ground water from the carbonate aquifers of the headwaters part of the basin is probably rather hard judging from chemical analyses of surface water in these areas. Water from the phyllites, gneisses, quartzites and conglomerates probably is only slightly mineralized. Additional data on natural ground water quality are currently being collected by the Geological Survey.

Water from the Kanawha River alluvium is usually softer than water from the bedrock but commonly has high acidity and a high iron content.

Little Kanawha River Basin

Surface Water Resources

Quantity

The Little Kanawha River and its tributaries tend to be "flashy" resulting in below average dry-weather flows. However, owing to similar terrain, geology, and precipitation, the streamflow characteristics throughout the entire Little Kanawha River Basin are relatively uniform and the basin probably has the least areal variation of flow of any major basin in West Virginia. There are no major storage reservoirs in the basin, but the Corps of Engineers is studying a site at Burnsville on the Little Kanawha River and sites on Leading Creek and West Fork. The Burnsville Reservoir Project is in advance planning stage.

In the past, the Little Kanawha River was navigable over much of its main stem, but navigation in recent years has been limited to mile point 3.8. However, the completion of the new high-level dam on the Ohio River at Belleville will extend the pool up the Little Kanawha River to about mile point 22 at the community of Newark, West Virginia.

Streamflow data shown in Table 5b were excerpted from data prepared by the Corps of Engineers.1/

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

Quality

Surface water of the Little Kanawha River Basin is soft (less than 60 mg/l) and either calcium magnesium bicarbonate or sulfate type water. Iron and manganese range between 0.3 to 1.0 mg/l and the water is moderately mineralized. Due to coal mining in some of the minor tributary basins, water from these tributaries contribute sulfate and noncarbonate hardness to the waters of the main stem, but the flows from these tributaries are too small to seriously affect the quality of the water in the main stem.

Ground Water Resources

Quantity

The Little Kanawha River Basin is underlain by consolidated sedimentary rocks of the Pennsylvanian and Permian age. Except for the Burning Springs anticline, near the middle of the basin, the rocks are relatively flat lying. Except for the headwaters portion of the basin from Kanawha Head to Fallsmill, where permeable sandstones of the Allegheny formation form the bedrock surface, most of the basin is underlain by shales, sandstones, and coal of the Monongahela formation and Dunkard group, which are relatively poor aquifers.

Extensive deposits of unconsolidated alluvium as much as 50 feet thick are present along the lower reaches of the river between Elizabeth and Parkersburg and are the best source of ground water in the basin. Wells tapping sand and gravel aquifers yield as much as 100 gpm.

Quality

Water from the principal bedrock aquifers is usually very soft, with hardness expressed as calcium carbonate about 15 mg/l, sulfate content about 12 mg/l, and total dissolved solids about 34 mg/l. In the vicinity of Burning Springs, erosion of a major anticlinal structure has exposed rocks containing relatively shallow, more mineralized ground water, where hardness averages about 160 mg/l expressed as $CaCO_3$ and total dissolved solids are about 240 mg/l.

Ground water from the municipal wells tapping unconsolidated sand and gravel aquifers at Elizabeth is soft, with a total hardness of 42 mg/l and only slightly mineralized with dissolved solid content of 110 mg/l.

IV THE ECONOMY

The Kanawha-Little Kanawha subarea of the Projective Economic Study is roughly coextensive with the watersheds of the Kanawha and the Little Kanawha Rivers, with the exception of the lower reaches of both streams. The subarea lies partly in the three States of West Virginia, Virginia, and North Carolina. To facilitate estimates of future water requirements and waste loads, the subarea has been divided into nine minor areas. Minor areas G-1, G-2, and G-4 contain the five northern counties of the Kanawha River Basin and minor area G-3 roughly encompasses the Little Kanawha River Basin. Minor areas G-5, G-6, and G-7 contain the ten middle counties of the Kanawha River Basin and minor areas G-8 and G-9 contain the eleven southern counties located in Virginia and North Carolina. All of the Kanawha-Little Kanawha subarea lies within the region designated as Appalachia. The counties in each minor area are listed in Tables 6 and 7 and shown on Figure 5-1, page 5-47.

Economic Profiles

Minor Areas G-1, G-2, G-3, and G-4

These minor areas have been grouped together because of their geographical location but G-2, which is Kanawha County, is the dominant minor area in the group. The 1960 population of these minor areas was 350,600, of which about 72 percent resided in Kanawha County and the remainder were located in the other eight counties in minor areas G-1, G-3, and G-4. The four larger cities in these northern counties are Charleston, South Charleston, St. Albans, and Dunbar, located in Kanawha County, having populations of 85,800, 19,200, 15,100, and 11,000 respectively. The average personal income for minor area G-2 was $1,771 and for the remaining minor areas $1,014 compared with $1,378 for the State of West Virginia.

Manufacturing, the most important employment category, is centered primarily in minor area G-2, Kanawha County, which accounts for 80 percent of the total manufacturing employment and 82 percent of the total manufacturing output in these minor areas. In these four minor areas, there were 26 manufacturing establishments employing 100 or more workers in 1964. The most important

industries are chemicals and allied products, other durables primary and fabricated metals, and food processing. Seven thermal power generating plants are located in minor area G-2, having a total capacity of 803 megawatts. There are also three hydropower generating stations, located at the navigation dams on the Kanawha River with a total capacity of 43.6 megawatts. One is located in Putman County, minor area G-1 with a capacity of 14.8 megawatts and the other two are located in minor area G-2 with a combined capacity of 28.8 megawatts.

Mining is the second most important employment category. Coal and oil productions are the most important mining activities. In 1960, 10.6 million tons of coal were produced equaling 9 percent of the total production in West Virginia. In 1963, 285 new gas wells, 28 new oil wells, and 151 new wells of both gas and oil were brought into production, representing 44.4 percent, 28.9 percent, and 69 percent respectively of the total number of new wells drilled in West Virginia in that year.

The total value of farm products sold has been maintained at about the 1959 figure of $8.8 million, 74.1 percent of which was accounted for by livestock products. During the period 1954-1959, 229,000 acres were taken out of farm production. Less than 50 acres were irrigated in 1959. Agricultural employment declined from 12,600 in 1950 to 3,600 in 1960.

Minor Areas G-5, G-6, and G-7

The total 1960 population of these minor areas was 347,300 and had an average personal per capita income of $1,109 compared to $1,378 for West Virginia. Two larger cities were located in the area, Beckley in Raleigh County and Bluefield in Mercer County, having populations of 18,600 and 19,300 respectively. In 1960, 19.2 percent of the total population was classified as urban.

Mining was the most important employment category. In 1960, 24.2 million tons of coal were produced representing 20.4 percent of the total yearly production in West Virginia. In 1963, 27 new gas wells were drilled representing 4.2 percent of the total yearly number in the State.

Manufacturing was the second most important employment category. Establishments employing 100 or more workers increased from 18 in 1958 to 21 in 1964. The most important industries are

furniture and wood products, primary and fabricated metals, food processing, and machinery (including electrical machinery). Two thermal power generating plants are located in the area, one in Fayette County and one in Greenbrier County, with a total capacity of 129.6 megawatts. One hydropower generating plant is located in Fayette County with a capacity of 102 megawatts.

Agricultural employment declined from 10,500 in 1950 to 3,800 in 1960. The total value of farm products sold increased from $12.1 million in 1954 to $14.8 million in 1959. Sixty-nine percent of the latter figure was accounted for by livestock products. During the same period, 301,000 acres were taken out of farm production. Less than 100 acres were irrigated in 1959.

Minor Areas G-8 and G-9

The total 1960 population of minor areas G-8 and G-9 was 201,500, 16.4 percent classified as urban. Average personal per capita income amounted to $1,027 compared to $1,598 in Virginia and $1,252 in North Carolina. Pulaski and Radford, Virginia, were the largest cities in the minor areas with populations of 10,500 and 9,400 respectively.

Manufacturing was the most important employment category and has shown a healthy rate of growth. Establishments employing 100 workers or more increased from 35 in 1958 to 53 in 1964. The most important industries are textiles, furniture and wood products, chemicals and allied products, and apparel and other fabricated products. Three thermal power generating plants are located in minor area G-8 with a total capacity of 443.1 megawatts. There are also three hydropower generating stations located in minor area G-8 with a total capacity of 105.1 megawatts.

Agricultural employment declined from 22,500 in 1950 to 11,200 in 1960. The total value of farm products sold increased from $23.9 million in 1954 to $33.4 million in 1959. Approximately 75 percent of the latter figure was accounted for by livestock products. During the same period of time, 1954-1959, 163,000 acres were taken out of farm production. Less than 1,000 acres were irrigated in 1959.

Mining activity is mainly confined to extraction of stone, sand, and gravel. However, there is a limited amount of mining of copper, lead and zinc, and some iron pigment.

Projected Population and Industrial Activity

Population of the Kanawha-Little Kanawha subarea is projected to increase from 914,000 in 1960 to about 1,480,000 by the year 2020. The 1960 population of the subarea accounted for 4.8 percent of the total Ohio River Basin population but is expected to account for only 4.3 percent by the year 2020. Table 6 shows the 1960 and projected population for the minor areas.

According to the Projective Economic Study, agricultural output is expected to increase from $200.7 million in 1960 to $242 million in 2010. Mining output is expected to increase from $243.9 million in 1960 to $807.3 million by 2010. The largest gain is expected to occur in manufacturing output. It is expected to increase from $1.5 billion to over $8 billion by 2010. Table 7 shows manufacturing output, total employment, and manufacturing employment. Projections to 1980, 2000, and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Kanawha-Little Kanawha subarea in the Projective Economic Study, nine other counties have land area within the Kanawha River Basin and four other counties have land area within the Little Kanawha River Basin. These counties are listed in Tables 8a and 8b respectively. Some of these counties have significant water using communities and significant sources of pollution within the basin, and projections of their water needs and organic waste loads are based on the projections of the Projective Economic Study subarea wherein they lie or to which they are contiguous.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Kanawha River Basin

Present and Projected Water Use

There are 179 central water supply systems in the Kanawha River Basin, serving a population of 441,575. The average daily water use is 44.192 mgd, amounting to 100 gallons per capita daily use.

In the basin, 78 percent of the water used for municipal supplies is from surface sources. Charleston, utilizing surface sources, accounts for approximately 43 percent of the total municipal water use in the basin.

The present municipal and industrial water use in the basin is listed by county and totaled for economic subareas and the basin in Table 9a. Within the minor area designation G-2, the city of Charleston, West Virginia, accounts for approximately 63 percent of the population served by central systems and about 90 percent of the water used from municipal systems.

The major industrial water use is for the chemical and allied product industries located in Kanawha County. This use accounts for about 95 percent of the total industrial water use within the entire basin.

Based on population increase and projected industrial activity, estimated water use will increase in the Kanawha River Basin as shown in Table 10a. It is estimated that total municipal and industrial water requirements will increase about threefold by the year 2020. The major increases will probably occur in or about the present centers of population and industrial activity. Increases in total water use in the minor areas by 2020 are projected to be 12 times the present use in minor area G-9, over 6 times the present use in minor area G-1, about 4.5 times the present use in minor areas G-4 and G-8 and, in other areas in the basin not included in Subarea G, over 3.5 times in minor areas G-5 and G-7, over 2.5 times the present use in minor area G-2 and twofold in minor area G-6.

Water Supply Problems

The projected total water supply figures shown in Table 10a, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey1/ were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11a are problem areas with the approximate time of onset.

TABLE 11a

KANAWHA RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Beckley, W.Va.	G-5		X		
Wytheville, Va.	G-8		X		
Pearisburg, Va.	G-8	X			
Narrows, Va.	G-8	X			
Boone, N. C.	G-9	X			

In minor area G-5, the total water use is projected to increase to 10.3 mgd by 1980, to 13.8 mgd by 2000, and to 21.2 mgd by 2020. Approximately 65 percent of the projected water use in this subarea will be for industrial use. It is assumed that increased industrial activity will occur in the area of the now-increasing industrial development in the Beckley area in Raleigh County. Beckley is presently planning for a solution of its water supply problems.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

In minor area G-8, total water use is projected to increase from 42.5 mgd at present to 132.5 mgd in 1980, to 159.9 mgd by 2000, and to about 185 mgd by 2020. In this minor area in Virginia, Wytheville in Wythe County and Pearisburg and Narrows in Giles County have experienced shortages of supply. In all these locations, ample supplies of surface water are nearby. At Wytheville, additional local impoundments should provide storage to meet future needs. Pearisburg and Narrows are located on the New River where supplies are plentiful and quality of water in the river is very good and could be developed as a source of supply.

In minor area G-9 in North Carolina, total water use is projected to increase from the present 1 mgd to about 11 mgd by 2020. Ground and surface supplies are ample to meet future needs and the community of Boone in Watauga County by enlarging its intake facilities can meet future needs.

Little Kanawha River Basin

Present and Projected Water Use

There are only eight central water supply systems in the Little Kanawha River Basin which obtain their water from sources within the basin. These systems serve a population of 9,700. The average daily water use is 0.735 mgd, amounting to 75 gallons per capita daily use. The city of Parkersburg, West Virginia, is located at the mouth of the Little Kanawha River but obtains its supply from five infiltration wells located along the Ohio River. The city serves a population of 60,000 and utilizes some 4.9 mgd for a 82 gallon per capita per day water use.

In the basin, 93 percent of the water used for municipal supplies is from surface sources.

The present municipal and industrial water use in the basin is listed by county and totaled for economic subareas and the basin in Table 9b.

The Little Kanawha River Basin contains very few water using industries. Due to the topography of the basin, transportation facilities, etc., the industrial activity within the basin (with the exception of extractive industries) is limited for the most part to the Parkersburg area along the Ohio River.

Based on population increase and projected industrial activity, estimated water use will increase in the Little Kanawha River Basin as shown in Table 10b. It is estimated that total municipal and industrial water requirements will increase about threefold by the year 2020.

Water Supply Problems

The projected total water supply figures shown in Table 10b, the 1 day in 30 years low flow data given in Table 5b, and availability of ground water as reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to the need for future development of sources of water supply.

In minor area G-4, total water use is projected to increase to .4 mgd by 1980, to .5 mgd by 2000, and to .7 mgd by 2020.

The problem area in the basin is shown in Table 11b.

TABLE 11b

LITTLE KANAWHA RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Spencer, W.Va.	G-4	X			

Approximately 50 percent of the projected water use in this subarea will be for industrial use. It is assumed that the increase in the smaller industries' use of the only supply available is at Spencer, the largest incorporated community in Roane County. Spencer is presently experiencing shortage of supply during the drier months. Construction of local impoundments should provide sufficient storage to meet future needs.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

A large industrial water use is projected in other areas in the basin not included in the G-4 minor area. This use is projected in the lower reaches of the Little Kanawha River which will be navigable in the near future due to the new higher pool of Belleville Dam on the Ohio River. Ample supply of water should be available to meet future needs.

VI WATER QUALITY CONTROL

Kanawha River Basin

Present and Projected Waste Loads

Present raw waste loads generated in the Kanawha River Basin are shown in Table 12a. The Charleston industrial complex is largely within minor area G-2 and this area accounts for 42 percent of the total municipal base load generated within the basin. Minor area G-2 contributes 78 percent of the total industrial organic waste load generated in the Kanawha Basin.

Shown in Table 13a are the present and projected raw waste loads for the various minor areas. Raw waste loads are projected to increase on the average of 1.5 times by the year 1980, 2.2 times by 2000, and 3.5 times by 2020.

Water Quality Control Problems

Listed in Table 14a are the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures for pollution control. The raw waste loads are assumed to have received secondary treatment or equivalent reduction before discharge to the stream.

TABLE 14a

KANAWHA RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date: Present	1980	2000	2020
Kanawha River	Charleston 1/	G-2	X			
Piney Creek	Beckley 1/	G-5			X	
E.Fk. Greenbrier River	Durbin 1/	G-6	X			
Bluestone River	Bluefield 1/	G-8	X			
Peak Creek	Pulaski 2/	G-8		X		
Chestnut Creek	Galax 2/	G-8		X		
Buffalo Creek	W. Jefferson 3/	G-9		X		

1/ West Virginia
2/ Virginia
3/ North Carolina

As previously indicated, the major municipal and industrial organic waste loads in the basin occur in the reach of the Kanawha River below the Charleston complex, where the chemical and allied product industries are the most prevalent. The organic portion of their waste loads is only one of a number of pollution aspects attributed to this type of industrial waste. Other major problems are toxicity, color, and taste/odor properties.

Therefore, the major water quality control problem within the Kanawha River Basin is that due to municipal and industrial discharges in the lower portions of the Kanawha River main stem. This results in degradation of the quality of the Kanawha River from mile point 70 to its mouth with serious degradation resulting in septic conditions during ow flow periods in various reaches of the Kanawha River from below Charleston to mile point 31.3 at the Winfield Dam. The present 7-day once in ten-year low flow condition for the Kanawha River at Charleston, as modified by the Sutton and Summersville Reservoirs, is 1,930 cfs. Detailed studies of the Kanawha River Basin indicate that a total flow of 4,700 cfs is presently needed during the low flow period in order to maintain a minimum dissolved oxygen concentration of 4 mg/l within this stream stretch and 5 mg/l at the mouth. These flow needs will increase with projected loadings to 6,900 cfs by 1980, 10,200 cfs by 2000 and 14,500 cfs by 2020 in the critical time of year.

The degree of treatment of organic wastes upon which the forestated flows are based are 85 percent removal of first stage BOD and 65 percent removal of second stage BOD.

Other stream reaches where problems exist at the present due to low flow in the receiving streams being insufficient to assimilate treated wastes residuals are East Fork Greenbrier River below Durbin, West Virginia, and Bluestone River below Bluefield, Virginia. Design flow in these streams is 1 cfs or less. In the East Fork Greenbrier River, total flows in the order of 15 cfs are needed now and, based on a projected declining industrial activity, this flow should meet future needs. In the Bluestone River, flows in the order of 10 cfs are needed at the present, increasing to 15 cfs by 1980, 20 cfs by 2000, and about 33 cfs by 2020. In Buffalo Creek, below West Jefferson, North Carolina, flows in the order of 5 cfs are needed by 1980, increasing to 10 cfs by 2000, and 15 cfs by 2020.

Need for additional flow is indicated by 1980 in Peak Creek below Pulaski, Virginia, and Chestnut Creek below Galax, Virginia. Design flow in these streams is 6 cfs and 16 cfs respectively. In Peak Creek beginning in 1980, flows in the order of 15 cfs will be needed, increasing to 17 cfs by 2000, and to 21 cfs by 2020. In Chestnut Creek beginning in 1980, flows in the order of 22 cfs will be needed, increasing to 24 cfs by 2000, and 26 cfs by 2020.

Another area of need is Piney Creek below Beckley, West Virginia, where by 2000 the design flow of 20 cfs will need to be increased to 22 cfs to assimilate residual organic wastes discharged to the stream. By 2020, the need will increase to 32 cfs.

Since all of the communities listed in Table 14a, except Charleston, West Virginia, are in headwater regions of tributary streams, it is doubtful whether storage for streamflow regulation can be developed above these communities and intensive treatment is indicated. There are undoubtedly many other small streams affected by discharge of residual organic wastes remaining after secondary treatment, but it is beyond the scope of this report to define them all.

Problems unrelated to population are heat discharge to streams and mine drainage. The Kanawha River in pool from Winfield Dam receives a large quantity of heat discharged from industry in the area. Adding to the heat load from industry is the heat discharged by seven thermal power generating plants with a total capacity of 803 megawatts located in Kanawha County. Under present regulated flow conditions, temperatures in the stream apparently do not exceed the maximum suggested temperature of 93°F. However, as industrial activity increases and heat discharges increase, off-stream treatment of cooling water may be required to control in-stream temperatures.

Mine drainage affects many minor tributaries in the basin especially in the Coal River subbasin. However, main stem reaches are not adversely affected except to increase hardness and iron content. These discharges must be controlled at their source in order to correct stream conditions.

Little Kanawha River Basin

Present and Projected Waste Loads

Present base municipal and industrial organic waste loads generated are shown in Table 12b. The majority of the industries within the Little Kanawha River Basin are concentrated in the Parkersburg, Wood County, West Virginia, area at the mouth of the Little Kanawha River. The present pool of the Ohio River extends to mile point 3.8 of the Little Kanawha River and the industrial activity is for the most part restricted to the main stem Ohio River and this pool area. About 94 percent of the total estimated base industrial organic load generated for the Little Kanawha River Basin is located in this pool area.

Consideration of the extent of the pool area is quite important since the water quality of the Little Kanawha River above this pool is much better than that of the Ohio River at this point. Also, this pool area has an embayment action due to the fact that the flow of the Little Kanawha River is extremely small in comparison with that of the Ohio River. The new Belleville Dam on the Ohio River, to be completed by 1968, will increase the slackwater of the Little Kanawha River to about mile point 22.

Table 13b contains the base and projected waste loads generated for the minor areas. Waste loads are projected to increase on an average of 1.4 times by the year 1980, 2.1 times by 2000, and 2.9 times by 2020.

Water Quality Control Problems

Table 14b contains a list of the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures for pollution control beyond the assumed secondary treatment or equivalent reduction for all organic wastes.

TABLE 14b

LITTLE KANAWHA RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Little Kanawha River	Mile point 3.8 to mouth		X			
Little Kanawha River	Mile point 22 to mouth			X		

The possible water quality control problem within the Little Kanawha River Basin is that of the Ohio River pool area at its mouth. The existing 3.8 mile pool area is degraded from industrial wastes and also from the lower water quality of the Ohio River as compared to that of the Little Kanawha River water. Recent studies indicate a serious sedimentation problem in the main stem of the Little Kanawha because of soil characteristics and low gradient of the stream. Even with good land use and conservation practices, it is believed sedimentation of the stream channel will continue to be a problem during low flow periods when stream velocities are low. When the Belleville Locks and Dam become operable, it is estimated that flows in the order of 300 cfs will need to be maintained at the head of the backwater area to provide acceptable water quality after secondary treatment of all organic wastes and silt-reduction remedial measures are applied.

TABLES

TABLE 1a

KANAWHA RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
North Carolina	*	Alleghany	99.1
" "	*	Ashe	100.0
Virginia	*	Bland	86.8
West Virginia	*	Boone	86.1
" "	*	Braxton	55.2
" "		Cabell	3.5
Virginia	*	Carroll	88.0
West Virginia	*	Clay	96.9
Virginia		Craig	15.0
West Virginia	*	Fayette	100.0
Virginia	*	Floyd	89.3
"	*	Giles	95.4
"	*	Grayson	100.0
West Virginia	*	Greenbrier	100.0
" "		Jackson	15.3
" "	*	Kanawha	100.0
" "		Lincoln	11.6
" "		Logan	13.7
" "		Mason	46.8
" "	*	Mercer	100.0
" "	*	Monroe	84.6
Virginia	*	Montgomery	44.4
West Virginia	*	Nicholas	100.0
" "	*	Pocahontas	96.4
Virginia	*	Pulaski	100.0
West Virginia	*	Putnam	76.3
" "	*	Raleigh	83.7
" "		Randolph	8.7
" "	*	Roane	50.3
Virginia		Smyth	6.5
West Virginia	*	Summers	100.0
Virginia		Tazewell	26.4
North Carolina	*	Watauga	36.1
West Virginia	*	Webster	96.4
Virginia	*	Wythe	100.0

*Counties considered in the Projective Economic Study of the Kanawha River Basin.

TABLE 2a

KANAWHA RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Kanawha River	12,300	97	0
Elk River	1,540	172	58
Gauley River	1,440	104	97
New River	6,920	320	97
Greenbrier River 1/	1,500	165	161

1/ Tributary of New River.

TABLE 3a

KANAWHA RIVER BASIN

Populations of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Charleston	Kanawha	West Va.	22,996	39,608	60,408	67,914	73,501	85,796
Bluefield	Mercer	" "	11,188	15,282	19,339	20,641	21,506	19,256
South Charleston 1/	Kanawha	" "	-	3,650	5,904	10,377	16,686	19,180
Beckley	Raleigh	" "	2,161	4,149	9,357	12,852	19,397	18,642
St. Albans 1/	Kanawha	" "	1,209	2,825	3,254	3,558	9,870	15,103
Dunbar 1/	"	" "	-	-	4,189	5,266	8,032	11,006
Pulaski	Pulaski	Virginia	4,807	5,282	7,168	8,792	9,202	10,469
Radford	Ind.City	"	4,202	4,627	6,227	6,990	9,026	9,371
Princeton	Mercer	West Va.	3,027	6,224	6,955	7,426	8,279	8,393
Blacksburg	Montgomery	Virginia	875	1,095	1,406	2,133	3,358	7,070
Nitro 1/	Putnam Kanawha	West Va.	-	-	-	2,983	3,314	6,894
Whytheville	Wythe	Virginia	3,054	2,947	3,327	4,653	5,513	5,634
Galax	Ind.City	"	-	-	-	3,195	5,248	5,254
Hinton	Summers	West Va.	3,656	3,912	6,654	5,815	5,780	5,197

1/ Part of Charleston, West Virginia urbanized area.

TABLE 1b

LITTLE KANAWHA RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
West Virginia	*	Braxton	44.8
" "	*	Calhoun	100.0
" "	*	Clay	3.1
" "		Doddridge	20.3
" "	*	Gilmer	100.0
" "		Lewis	37.5
" "	*	Ritchie	100.0
" "	*	Roane	41.2
" "		Upshur	17.0
" "	*	Webster	3.6
" "	*	Wirt	99.1
" "		Wood	54.1

*Counties considered in the Projective Economic Study of the Kanawha and Little Kanawha River Basins.

TABLE 2b

LITTLE KANAWHA RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Little Kanawha River	2,320	160	0
Hughes River	530	North Fork 50 South Fork 40	19

TABLE 3b

LITTLE KANAWHA RIVER BASIN

Populations of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Spencer	Roane	West Va.	1,224	1,765	2,493	2,497	2,587	2,660
Glenville	Gilmer	" "	336	327	799	588	1,789	1,828
Pennsboro	Ritchie	" "	930	1,654	1,616	1,738	1,753	1,660
Harrisville	"	" "	608	1,036	1,192	1,338	1,387	1,428

TABLE 4

KANAWHA-LITTLE KANAWHA RIVER BASINS

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Pool Area2/ (acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Bluestone	F, R	1,970	600,100		36,500
Claytor	P, R	4,540			232,000
Summersville	F, R, A	2,723 1/	390,800		163,400 1/
Sutton	F, R, A	1,520 1/	261,200		60,100 1/
Byllesby	P	335			3,540
Stevens Branch L.	R	303			8,000
Hawks Nest	P	243			7,346
Plum Orchard Lake	R	202			2,625
Sherwood Lake	R	164			4,020
Moncove Lake	R	135			2,284
Little River	P	113			1,020
Glade Creek	W	110		1,230	
Flattop Lake Assn.	R	225			

1/ Low flow regulation - seasonal.
2/ Pool maintained during summer season, except as noted.
F - Flood Control
P - Hydroelectric Power
A - Low Flow Regulation
R - Recreation
W - Water Supply

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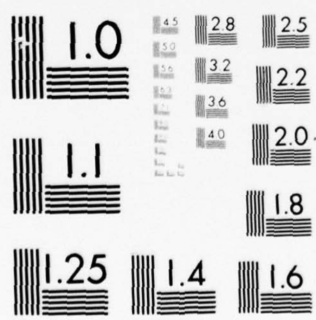

MICROCOPY RESOLUTION TEST CHART
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TABLE 5a

KANAWHA RIVER BASIN

Flow Data[2/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)[3/]	1 Day in 30 Yrs. Low Flow (cfs)[3/]
Kanawha River						
Kanawha Falls, W. Va.	8,367	12,580	640	320,000		
Charleston, W. Va.	10,419	10,367	1,030	216,000	1,200	880
New River						
Galax, Va.	1,131	1,801	193	141,000	359	259
Ivanhoe, Va.	1,340	2,040	184	155,000	398	232
Allisonia, Va.	2,202	3,010	412	185,000	634	
Radford, Va.	2,748	3,731[1/]	165	218,000	845	565
Glenlyn, Va.	3,768	4,929	770	226,000	1,050	735
Bluestone Dam	4,604	5,536	10(est.)	232,000		
Gauley River						
Summersville, W. Va.	680	1,536	0.6	77,500	5.5	1.6
Belva, W. Va.	1,315	2,633	3.2	105,000	12	4.8
At Mouth	1,440				13[3/]	5.2[3/]

TABLE 5a (cont'd)

KANAWHA RIVER BASIN

Flow Data 2/

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs) 3/	1 Day in 30 Yrs. Low Flow (cfs) 3/
Greenbrier River						
Buckeye, W. Va.	540	847	3.8	41,500	11	6
Alderson, W. Va.	1,357	1,993	24	77,500	42	30
Hilldale, W. Va.	1,625	2,152	39	47,800	56	34
Little Coal River						
Danville, W. Va.	270	337	0	42,800		
Elk River						
Centralia, W. Va.	281	650	1.0	18,300	3.7	1.2
Sutton, W. Va.	543	1,094	0.4	34,200	4	1.2
Queen Shoals, W. Va.	1,145	1,951	0.3	72,000	6.2	1.9
Bluestone River						
Pipestem, W. Va.	363	466	5.2	16,100		
Walkers Creek						
Bane, Va.	305	317	25	16,500	29	21
Wolf Creek						
Near Narrows, Va.	223	288	8.8	12,900	17	11

1/ Adjusted
2/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Study"
3/ Unmodified flows

TABLE 5b

LITTLE KANAWHA RIVER BASIN

Flow Data 1/

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Little Kanawha River						
Glenville, W. Va.	386	601	0	20,400		
Palestine, W. Va.	1,515	2,100	0.6	46,300	3.5	.8
Hughes River						
Cisco, W. Va.	452	435	12	25,200		

1/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Study"

TABLE 6

KANAWHA-LITTLE KANAWHA RIVER BASINS

Economic Subarea G
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation G-1									
West Va.	Putnam	23,600	1,500						
	Subtotal	23,600	1,500	32,800		38,900		50,000	
Area Designation G-2									
West Va.	Kanawha	252,900	168,900						
	Subtotal	252,900	168,900	328,300		408,800		455,000	
Area Designation G-3									
West Va.	Calhoun	7,900	0						
"	Gilmer	8,100	0						
"	Ritchie	10,900	0						
"	Wirt	4,400	0						
	Subtotal	31,300	0	31,000		33,300		34,800	
Area Designation G-4									
West Va.	Braxton	15,200	0						
"	Clay	11,900	0						
"	Roane	15,700	2,700						
	Subtotal	42,800	2,700	41,300		42,100		43,000	

TABLE 6 (cont'd)

KANAWHA-LITTLE KANAWHA RIVER BASINS

Economic Subarea G
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation G-5									
West Va.	Boone	28,800	0						
"	Fayette	61,700	6,900						
"	Raleigh	77,800	21,700						
	Subtotal	168,300	28,600	162,100		165,900		180,000	
Area Designation G-6									
West Va.	Greenbrier	34,400	2,700						
"	Nicholas	25,400	4,100						
"	Pocahontas	10,100	0						
"	Webster	13,700	0						
	Subtotal	83,600	6,800	77,000		71,500		68,500	
Area Designation G-7									
West Va.	Mercer	68,200	27,600						
"	Monroe	11,600	0						
"	Summers	15,600	5,200						
	Subtotal	95,400	32,800	104,100		106,900		108,000	

TABLE 6 (cont'd)

KANAWHA-LITTLE KANAWHA RIVER BASINS

Economic Subarea G
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation G-8									
Virginia	Bland	6,000	0						
"	Carroll	28,400	5,200						
"	Floyd	10,500	0						
"	Giles	17,200	2,500						
"	Grayson	17,400	0						
"	Montgomery	42,300	20,100						
"	Pulaski	27,300	10,500						
"	Wythe	22,000	5,600						
	Subtotal	171,100	43,900	228,300		289,200		359,000	
Area Designation G-9									
North Carolina	Alleghany	7,700	0						
"	Ashe	19,800	0						
"	Watauga	17,500	3,700						
	Subtotal	45,000	3,700	73,900		125,300		181,500	
TOTAL Subarea G		914,000	288,900	1.078,800	373,000	1,281,900	528,000	1,479,800	785,000

TABLE 7

KANAWHA-LITTLE KANAWHA RIVER BASINS

Economic Subarea G
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation G-1													
West Va.	Putnam	6,500	2,570										
	Subtotal	6,500	2,570	84.6	145	153	296	216	164	691	364	183	1608
Area Designation G-2													
West Va.	Kanawha	83,000	22,750										
	Subtotal	83,000	22,750	701.2	137	98	184	180	81	288	250	67	467
Area Designation G-3													
West Va.	Calhoun	2,100	360										
"	Gilmer	2,100	190										
"	Ritchie	3,100	670										
"	Wirt	1,200	310										
	Subtotal	8,500	1,530	32.9	113	149	241	137	209	516	164	235	1119
Area Designation G-4													
West Va.	Braxton	3,200	370										
"	Clay	2,100	440										
"	Roane	4,100	870										
	Subtotal	9,400	1,680	29.6	118	126	216	149	191	412	180	226	804

TABLE 7 (cont'd)

KANAWHA-LITTLE KANAWHA RIVER BASINS

Economic Subarea G
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation G-5													
West Va.	Boone	6,400	480										
"	Fayette	13,800	2,220										
"	Raleigh	18,700	1,780										
	Subtotal	38,900	4,480	102.1	118	108	182	146	134	336	180	179	530
Area Designation G-6													
West Va.	Greenbrier	10,100	1,090										
"	Nicholas	6,300	970										
"	Pocahontas	2,700	660										
"	Webster	2,700	320										
	Subtotal	21,800	3,040	60.1	106	86	132	114	59	178	124	53	252
Area Designation G-7													
West Va.	Mercer	18,900	2,410										
"	Monroe	3,400	860										
"	Summers	3,500	380										
	Subtotal	25,800	3,650	66.6	125	184	213	146	312	449	177	589	812

TABLE 7 (cont'd)

KANAWHA-LITTLE KANAWHA RIVER BASINS

Economic Subarea G
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation G-8													
Virginia	Bland	1,700	500										
"	Carroll	11,500	7,090										
"	Floyd	3,500	1,300										
"	Giles	5,400	2,300										
"	Grayson	6,200	2,800										
"	Montgomery	16,800	9,140										
"	Pulaski	9,500	4,200										
"	Wythe	6,900	1,600										
	Subtotal	61,500	28,930	349.3	143	135	235	193	137	431	260	138	811
Area Designation G-9													
North Carolina	Alleghany	2,900	960										
"	Ashe	6,100	1,930										
"	Watauga	5,400	930										
	Subtotal	14,400	3,820	54.7	174	276	371	314	589	960	509	868	238
Total Subarea G		269,800	72,450	1481.1	133	130	208	175	153	383	238	182	718

*In millions of 1960 dollars.
**1960 = 100

TABLE 8a

KANAWHA RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
West Virginia	Cabell	H-2	Ohio-Huntington
Virginia	Craig	*	
West Virginia	Jackson	H-3	Ohio-Huntington
" "	Lincoln	J-3	Guyandotte-Big Sandy-Little Sandy
" "	Logan	J-3	Guyandotte-Big Sandy-Little Sandy
" "	Mason	H-3	Ohio-Huntington
" "	Randolph	B-2	Monongahela
Virginia	Smyth	*	
"	Tazewell	*	

* - Not included in Projective Economic Study of Ohio River Basin.

TABLE 8b

LITTLE KANAWHA RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
West Virginia	Doddridge	E-1	Upper Ohio
" "	Lewis	B-1	Monongahela
" "	Upshur	B-2	Monongahela
" "	Wood	E-1	Upper Ohio

TABLE 9a

KANAWHA RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation G-1											
West Va.	Putnam	5	7,815	1,200	6,615	.740	.085	.655	95	Impoundment, Wells, Guano Creek	0
	Subtotal	5	7,815	1,200	6,615	.740	.085	.655	95		0
Area Designation G-2											
West Va.	Kanawha	30	173,755	6,910	166,845	21.191	.709	20.482	122	Kanawha, Elk, Coal and Pocatalico Rivers, Wells	1395.0
	Subtotal	30	173,755	6,910	166,845	21.191	.709	20.482	122		1395.0
Area Designation G-4											
West Va.	Braxton	2	2,470		2,470	.216		.216	88	Elk River	.5
"	Clay	3	1,600		1,600	.105		.105	66	Elk River, Wells	0
"	Roane	0									0
	Subtotal	5	4,070		4,070	.321		.321	79		.5
Area Designation G-5											
West Va.	Boone	7	6,495	2,705	3,790	.602	.299	.303	93	Pond Fork and Marsh Fork of Coal River, Wells	0
"	Fayette	36	50,295	29,080	21,215	5.377	3.166	2.211	107	Kanawha R., Mines, Springs, Wells	56.5
"	Raleigh	16	33,810	4,870	28,940	2.741	.407	2.334	81	Coal River, Wells and Springs	0
	Subtotal	59	90,600	36,655	53,945	8.720	3.872	4.848	97		56.5

TABLE 9a (cont'd)

KANAWHA RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation G-6											
West Va.	Greenbrier	13	16,105	8,105	8,000	1.137	.629	.508	71	Greenbrier R., Wells and Mine	.1
"	Nicholas	2	6,110	4,110	2,000	.380	.300	.080	62	Wells, Cherry R., Muddlety River	.2
"	Pocahontas	3	2,430		2,430	.325		.325	134	Knapp Creek, Leatherbark Creek	.1
"	Webster	4	2,865		2,865	.193		.193	68	Elk R., Gauley R., Leatherwood Creek	0
	Subtotal	22	27,510	12,215	15,295	2.035	.929	1.106	74		.4
Area Designation G-7											
West Va.	Mercer	12	38,400	36,900	1,500	2.565	2.405	.160	67	Wells, Bluestone River	.5
"	Monroe	3	2,700	1,300	1,400	.215	.105	.110	80	Greenbrier River, Springs, Wells	0
"	Summers	1	5,500		5,500	.300		.300	55	New River	0
	Subtotal	16	46,600	38,200	8,400	3.080	2.510	.570	66		.5
Area Designation G-8											
Virginia	Bland	3	1,450	1,280	170	.101	.090	.011	70	Springs	0
"	Carroll	2	7,200		7,200*	.810		.810	113	Reed Island Crk., Springs, Chestnut Crk.	0
"	Floyd	1	500		500	.050		.050	100	Dodd Creek	0
"	Giles	10	9,850	6,950	2,900	.729	.529	.200	74	Springs, Mill Creek	6.9
"	Grayson	2	3,400	1,200	2,200	.150	.050	.100	44	Wells, Eagle Bottom Creek	.7
"	Montgomery	3	29,750	750	29,000	2.865	.040	2.825	97	New River, Springs	.6
"	Pulaski	4	14,025	3,025	11,000	1.210	.210	1.000	86	Mtn. Watersheds, Peak Creek, Wells	6.4
"	Wythe	4	8,750	1,550	7,200	.800	.095	.705	92	Vendrick Run, Reed Crk., New R., Springs	2.0
	Subtotal	29	74,925	14,755	60,170	6.715	1.014	5.701	90		16.6

TABLE 9a (cont'd)

KANAWHA RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation G-9											
North Carolina	Alleghany	1	1,100	1,100		.094	.094		85	Wells	0
"	Ashe	3	1,500	1,500		.105	.105		70	Wells and Springs	.2
"	Watauga	3	5,350	3,050	2,300	.410	.270	.140	77	Winkler Creek, Brickhouse Crk., Wells	.1
	Subtotal	7	7,950	5,650	2,300	.609	.469	.140	76		.3
Other Areas in Basin											
West Va.	Logan	2	350	250	100	.037	.030	.007	106	Wells, Beach Creek	0
Virginia	Tazewell	4	8,000	800	7,200	.744	.054	.690	104	Bluestone R., Big Spring Br., Wells	.1
	Subtotal	6	8,350	1,050	7,300	.781	.084	.697	104		0.1
	TOTAL	179	441,575	116,635	324,940	44.192	9.672	34.520	100		1469.9

Note: For Area Designation G-3 see Little Kanawha River Basin.

TABLE 10a

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation G-1												
From Central Supplies	7,820	95	.7	10,800	105	1.1	16,700	118	2.0	27,800	128	3.6
Industrial			0			.2			.4			.9
Subtotal			.7			1.3			2.4			4.5
Area Designation G-2												
From Central Supplies	173,800	122	21.2	247,000	138	34.1	368,000	150	55.0	525,000	160	84.0
Industrial			1395.0			1840.0			2550.0			3720.0
Subtotal			1416.2			1874.1			2605.0			3804.0
Area Designation G-4												
From Central Supplies	4,070	79	.3	4,300	92	.4	5,200	100	.5	6,850	110	.8
Industrial			.5			1.8			1.5			2.6
Subtotal			.8			2.2			2.0			3.4
Area Designation G-5												
From Central Supplies	90,600	97	8.7	95,000	108	10.3	116,000	119	13.8	163,000	130	21.2
Industrial			56.5			81.9			133.0			200.0
Subtotal			65.2			92.2			146.8			221.2

TABLE 10a (cont'd)

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation G-6												
From Central Supplies	27,500	74	2.0	27,800	90	2.5	30,500	100	3.1	37,900	110	4.2
Industrial			.4			.4			.5			.6
Subtotal			2.4			2.9			3.6			4.8
Area Designation G-7												
From Central Supplies	46,600	66	3.1	55,500	85	4.7	68,500	95	6.5	88,500	105	9.3
Industrial			.5			1.0			1.9			3.5
Subtotal			3.6			5.7			8.4			12.8
Area Designation G-8												
From Central Supplies	74,900	100	7.5	108,500	115	12.5	165,500	125	20.9	264,000	140	37.0
Industrial			35.0			120.0			139.0			148.0
Subtotal			42.5			132.5			159.9			185.0
Area Designation G-9												
From Central Supplies	7,950	76	.6	14,200	90	1.3	28,200	100	2.8	53,800	110	5.9
Industrial			.3			1.0			2.3			4.9
Subtotal			.9			2.3			5.1			10.8

TABLE 10a (cont'd)

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Other Areas in Basin												
From Central Supplies	8,350	104	.9	12,100	115	1.4	18,500	127	2.4	29,400	140	4.1
Industrial			.1			.2			.3			.5
Subtotal			1.0			1.6			2.7			4.6
Kanawha River Basin												
From Central Supplies Total	441,590	102	45.0	575,200	118	68.3	817,100	131	107.0	1,196,250	142	170.1
Industrial Total			1488.3			2046.5			2828.9			4081.0
GRAND TOTAL			1533.3			2114.8			2935.9			4251.1

TABLE 9b

LITTLE KANAWHA RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation G-3											
West Va.	Calhoun	1	800		800	.056		.056	70	Little Kanawha River	.1
"	Gilmer	1	1,400		1,400	.086		.086	62	Little Kanawha River	0
"	Ritchie	3	3,120	2,700	420	.223	.188	.035	72	Wells, N.Fk.of Hughes River	.1
"	Wirt	1	700	700		.045	.045		64	Wells	0
	Subtotal	6	6,020	3,400	2,620	.410	.233	.177	68		.2
Area Designation G-4											
West Va.	Braxton	1	680		680	.085		.085	125	Little Kanawha River	0
"	Clay	0									0
"	Roane	1	3,000		3,000	.240		.240	80	Spring Creek and Miletree Creek	0
	Subtotal	2	3,680		3,680	.325		.325	88		0
Other Areas in Basin											
West Va.	Wood	0									6.4
	Subtotal	0									6.4
	TOTAL	8	9,700	3,400	6,300	.735	.233	.502	75		6.6

Note: For Area Designations G-1, G-2, G-5, G-6, G-7, G-8 and G-9 see Kanawha River Basin.

TABLE 10b

LITTLE KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation G-3												
From Central Supplies	6,020	68	.4	6,500	86	.6	8,400	96	.8	11,200	105	1.2
Industrial			.2			.4			.7			1.4
Subtotal			.6			1.0			1.5			2.6
Area Designation G-4												
From Central Supplies	3,680	88	.3	3,900	98	.4	4,700	108	.5	6,200	120	.7
Industrial			0			.1			.3			.5
Subtotal			.3			.5			.8			1.2
Other Areas in Basin												
From Central Supplies			0			0			0			0
Industrial			6.4			9.1			13.1			18.1
Subtotal			6.4			9.1			13.1			18.1
Little Kanawha River Basin												
From Central Supplies Total	9,700	75	.7	10,400	96	1.0	13,100	99	1.3	17,400	109	1.9
Industrial Total			6.6			9.6			14.1			20.0
GRAND TOTAL			7.3			10.6			15.4			21.9

TABLE 12a

KANAWHA RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation G-1						
West Va.	Putnam	4	1,500	Kanawha River, Hurricane Creek	1,500	231,000
	Subtotal	4	1,500		1,500	231,000
Area Designation G-2						
West Va.	Kanawha	14	132,300	Kanawha River, Elk River, Coal R.	132,300	1,600,000
	Subtotal	14	132,300		132,300	1,600,000
Area Designation G-4						
West Va.	Braxton	2	1,880	Buffalo Creek, Elk River	1,880	1,100
"	Clay	1	300	Elk River	300	1,300
"	Roane	0				0
	Subtotal	3	2,180		2,180	2,400
Area Designation G-5						
West Va.	Boone	3	3,100	Little Coal River, Coal River	3,100	2,700
"	Fayette	8	13,330	Kanawha River, Creeks	13,300	5,400
"	Raleigh	5	19,940	Piney Creek, Little Whitestick Crk.	19,940	9,600
	Subtotal	16	36,370		36,370	17,700

TABLE 12a (cont'd)

KANAWHA RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation G-6						
West Va.	Greenbrier	7	12,520	Greenbrier R., Sewell Creek	12,520	500
"	Nicholas	2	5,700	Cherry River, Arbuckle Creek	5,700	3,100
"	Pocahontas	3	2,375	Knapp Creek, Greenbrier River	2,375	64,600
"	Webster	2	1,500	Back Fk.,Elk R.,Big Ditch Run	1,500	700
	Subtotal	14	22,095		22,095	68,900
Area Designation G-7						
West Va.	Mercer	5	31,885	Bluestone R.,Brush Cr.,East R.	31,885	14,000
"	Monroe	3	1,395	Greenbrier R., Rich Creek	1,395	2,500
"	Summers	1	5,250	New R.and Greenbrier River	5,250	1,100
	Subtotal	9	38,530		38,530	17,600
Area Designation G-8						
Virginia	Bland	1	500	Kimberling Creek	500	1,700
"	Carroll	2	6,150	Chestnut Creek, Little Reed Creek	6,150	8,700
"	Floyd	1	450	Dodds Creek	450	3,900
"	Giles	3	5,520	New R., Rich Creek	5,520	48,000
"	Grayson	1	120	New R.	120	6,400
"	Montgomery	3	25,900	Strubles Cr., New R., Crab Creek	25,900	15,700
"	Pulaski	2	19,650	Peak Creek, New R.	19,650	19,000
"	Wythe	2	6,450	Reed Creek	6,450	6,100
	Subtotal	14	64,740		64,740	109,500

TABLE 12a (cont'd)

KANAWHA RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation G-9						
North Carolina	Alleghany	1	1,000	Little River	1,000	200
"	Ashe	1	750	Buffalo Creek	750	2,600
"	Watauga	2	6,175	Boone Creek, New River	6,175	400
	Subtotal	4	7,925		7,925	3,200
Other Areas in Basin						
Virginia	Tazewell	2	6,315	Bluestone R., Laurel Fork Creek	6,315	0 1/
	Subtotal	2	6,315		6,315	0
	TOTAL	80	311,955		311,955	2,050,300

1/ - Included with Mercer County, West Virginia.

*NOT to be interpreted as waste loads to the stream.

TABLE 13a

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation G-1				
Domestic and Commercial	1,500	2,300	3,200	5,300
Industrial	231,000	520,000	988,800	2,069,700
Subtotal	232,500	522,300	992,000	2,075,000
Area Designation G-2				
Domestic and Commercial	132,300	188,000	280,500	400,000
Industrial	1,600,000	2,112,000	2,928,000	4,272,000
Subtotal	1,732,300	2,300,000	3,208,500	4,672,000
Area Designation G-4				
Domestic and Commercial	2,200	2,300	2,800	3,700
Industrial	2,400	3,900	7,300	12,400
Subtotal	4,600	6,200	10,100	16,100
Area Designation G-5				
Domestic and Commercial	36,400	38,200	46,600	65,500
Industrial	17,700	25,700	41,600	62,700
Subtotal	54,100	63,900	88,200	128,200

TABLE 13a (cont'd)

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation G-6				
Domestic and Commercial	22,100	22,300	24,500	30,500
Industrial	68,900	75,100	81,300	104,700
Subtotal	91,000	97,400	105,800	135,200
Area Designation G-7				
Domestic and Commercial	38,500	45,800	56,600	73,100
Industrial	17,600	34,800	66,900	123,200
Subtotal	56,100	80,600	123,500	196,300
Area Designation G-8				
Domestic and Commercial	64,700	93,800	143,000	227,700
Industrial	109,500	202,600	311,000	519,000
Subtotal	174,200	296,400	454,000	746,700
Area Designation G-9				
Domestic and Commercial	7,900	14,100	28,800	53,400
Industrial	3,200	10,400	24,800	52,000
Subtotal	11,100	24,500	53,600	105,400

TABLE 13a (cont'd)

KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Other Areas in Basin				
Domestic and Commercial	6,300	9,100	13,900	22,200
Industrial	0	2,000	3,800	7,000
Subtotal	6,300	11,100	17,700	29,200
Kanawha River Basin				
Domestic and Commercial Total	311,900	415,900	599,900	881,400
Industrial Total	2,050,300	2,986,500	4,453,500	7,222,700
GRAND TOTAL	2,362,200	3,402,400	5,053,400	8,104,100

*NOT to be interpreted as waste loads to the streams.

TABLE 12b

LITTLE KANAWHA RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation G-3						
West Va.	Calhoun	1	1,020	Little Kanawha River	1,020	1,100
"	Gilmer	1	1,300	Little Kanawha River	1,300	0
"	Ritchie	3	2,700	N.Fork Hughes River, Bunnel Run	2,700	2,500
"	Wirt	1	600	Little Kanawha River	600	0
	Subtotal	6	5,620		5,620	3,600
Area Designation G-4						
West Va.	Braxton	1	250	Little Kanawha River	250	0
"	Clay	0				0
"	Roane	1	1,800	Spring Creek	1,800	2,700
	Subtotal	2	2,050		2,050	2,700
Other Areas in Basin						
West Va.	Wood	0				104,000
	Subtotal	0				104,000
	TOTAL	8	7,670		7,670	110,300

*NOT to be interpreted as waste loads to the streams.

TABLE 13b

LITTLE KANAWHA RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation G-3				
Domestic and Commercial	7,670	8,300	10,700	14,300
Industrial	3,600	7,000	13,000	24,400
Subtotal	11,270	15,300	23,700	38,700
Area Designation G-4				
Domestic and Commercial	2,050	2,200	2,600	3,400
Industrial	2,700	4,400	8,200	13,900
Subtotal	4,750	6,600	10,800	17,300
Other Areas in Basin				
Domestic and Commercial	0	0	0	0
Industrial	104,000	147,600	212,200	293,300
Subtotal	104,000	147,600	212,200	293,300
Little Kanawha River Basin				
Domestic and Commercial Total	9,720	10,500	13,300	17,700
Industrial Total	110,300	159,000	233,400	331,600
GRAND TOTAL	120,020	169,500	246,700	349,300

*NOT to be interpreted as waste loads to the streams.

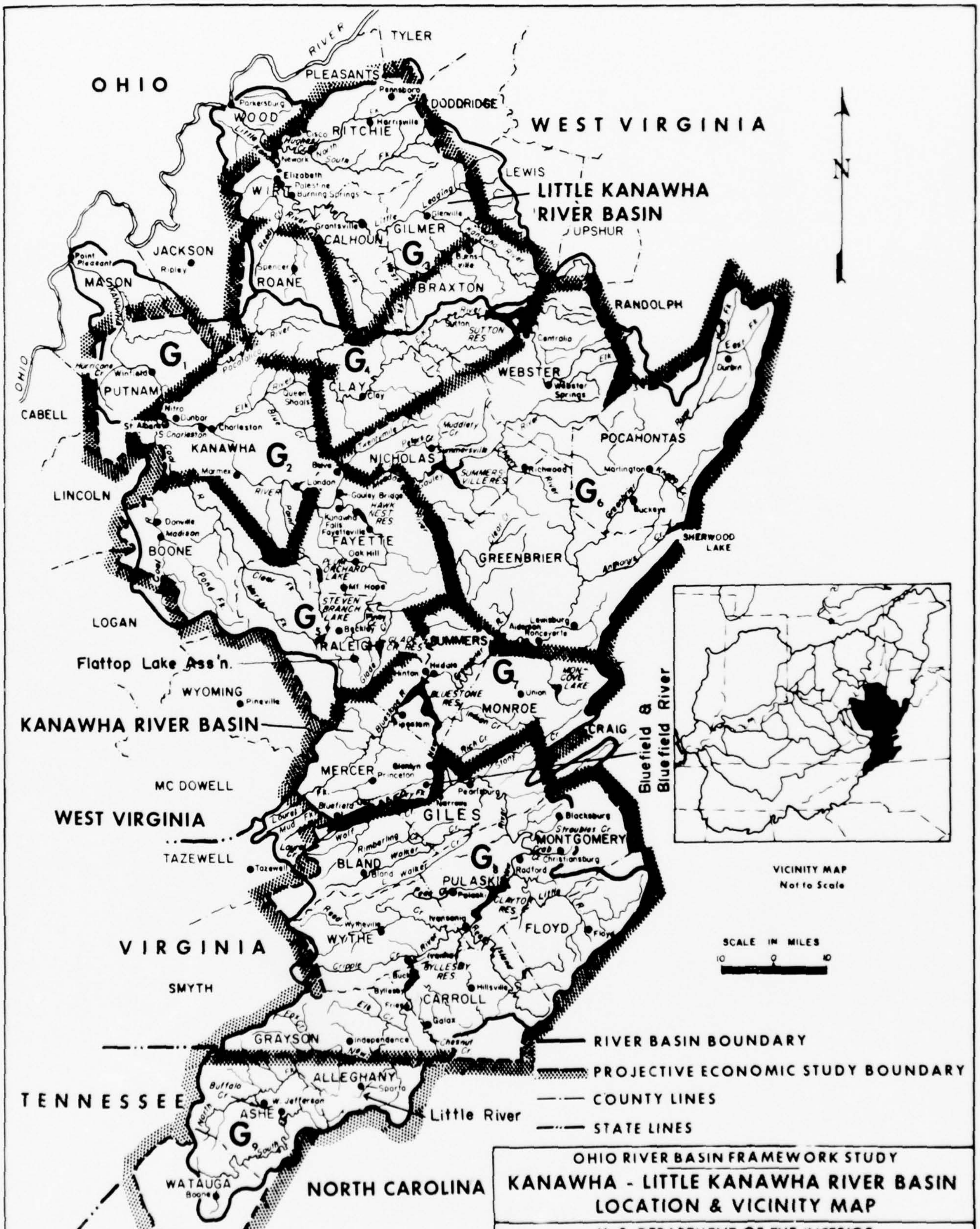
OHIO
WEST VIRGINIA
LITTLE KANAWHA RIVER BASIN
KANAWHA RIVER BASIN
Flattop Lake Ass'n.
WEST VIRGINIA
VIRGINIA
TENNESSEE
NORTH CAROLINA
Little River
Bluefield & Bluefield River
TYLER
PLEASANTS
DODDRIDGE
WOOD
RITCHIE
WIRT
LEWIS
UPSHUR
JACKSON
CALHOUN
GILMER
ROANE
BRAXTON
MASON
RANDOLPH
PUTNAM
CLAY
WEBSTER
CABELL
KANAWHA
NICHOLAS
POCAHONTAS
LINCOLN
FAYETTE
GREENBRIER
BOONE
LOGAN
RALEIGH
SUMMERS
MONROE
WYOMING
MERCER
CRAIG
MC DOWELL
GILES
MONTGOMERY
TAZEWELL
BLAND
PULASKI
FLOYD
WYTHE
SMYTH
CARROLL
GRAYSON
ALLEGHANY
ASHE
WATAUGA
SHERWOOD LAKE
SUTTON RES
SUMMERSVILLE RES
HAWK NEST RES
ORCHARD LAKE
STEVEN BRANCH LAKE
BLUESTONE RES
MONCOVE LAKE
CLAYTOR RES
BYLLESBY RES
VICINITY MAP
Not to Scale
SCALE IN MILES
10 0 10
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STUDY BOUNDARY
COUNTY LINES
STATE LINES
OHIO RIVER BASIN FRAMEWORK STUDY
KANAWHA - LITTLE KANAWHA RIVER BASIN
LOCATION & VICINITY MAP
U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 5-1

GUYANDOTTE-BIG SANDY-LITTLE SANDY RIVER BASINS

Subbasin Area
No. 6

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I SUMMARY

Municipal and Industrial Water Supply Problems

At the low rate of economic growth projected for the combined Guyandotte, Big Sandy and Little Sandy Basins, increases in water supply needs can be met from existing sources with only minor modifications. Only one water system in the region serves more than 10,000 people.

Water Quality Control Problems

Many of the communities in this basin are partially sewered. In the event that sewer systems are extended in these areas, there could be an increase in municipal organic waste loading discharged to the streams without an increase in population. Design streamflows are adequate to meet these needs without modification. If a large water using industry were to locate in the Big Sandy or Guyandotte Basins, there could then be a need for flows to assimilate wastes even after secondary treatment.

Quality is irregular in the lower reach of the Big Sandy in pool behind Greenup Dam on the Ohio River. There have been taste, odor, and hardness problems reported recently in this area and flow regulation would assure better water quality.

Progress is being made and should continue to be pressed in removing coal washing fines from discharges to the headwater streams and tributaries of the Guyandotte and Big Sandy Rivers.

II DESCRIPTION OF STUDY AREA

The Guyandotte, Big Sandy, and Little Sandy River Basins lie in southwestern West Virginia and eastern Kentucky. The rivers drain a hilly to mountainous area extending from just south of Portsmouth, Ohio, on the northwest, to southwestern Virginia on the south side and nearly as far east as Bluefield and Beckley, West Virginia, on the southeast. The Big Sandy River and Tug Fork form the entire length of the Kentucky-West Virginia boundary. The combined drainage area is 6,674 square miles. On the west are the Tygarts Creek, Licking River and Kentucky River drainage areas. To the south, drainage is to the Tennessee River, and to the east, to the Kanawha River. The basins are shown on Figure 6-1, page 6-53.

Guyandotte River Basin

Location and Boundaries

The Guyandotte River Basin is located in the mountains of southwestern West Virginia. It is the easternmost of the basins considered in this group. Its drainage area is 1,670 square miles, approximately 7 percent of the area of the State. The Big Sandy River Basin is to the west and the Kanawha River Basin is on the eastern side. The Guyandotte River has its source near Rhodell, West Virginia, in the southern portion of Raleigh County at the confluence of Winding Gulf and Stone Coal Creeks. It flows in a westerly direction for approximately 50 miles to the town of Gilbert, where it turns north and continues for 115 miles before discharging into the Ohio River at Huntington, about 305 miles below Pittsburgh, Pennsylvania. The only major tributary is the Mud River, which drains 358 square miles and enters the Guyandotte at Barboursville, seven miles from the mouth. Many small upper basin tributaries drain the important coal mining areas in Logan, Wyoming and part of Raleigh Counties. Table 1a lists the eight counties which lie wholly or partly in the basin. Table 2a summarizes pertinent information about the Guyandotte River and its major tributary.

Physical Features

The topography of the basin is mountainous and consists of a maze of hills and valleys. Elevation above sea level within the basin ranges from under 1,000 feet in the extreme lower portion of the basin to between 2,000 and 3,000 feet in the middle and upper portions of the basin. The slope of the upper half of the river averages 11 feet per mile. In the lower 71 miles, it averages 1.8 feet per mile. The Mud River follows the wide valley of the ancient Teays River for much of its lower length.

There are no natural lakes or large reservoirs in the basin at the present, but the Corps of Engineers is planning a reservoir on the Guyandotte River above Logan, West Virginia.

A large portion of the basin area is covered with second growth timber, and the remainder is chiefly pasture land. Natural gas is found in the northern part. There are coal seams under about 85 percent of the basin.

Climate

The climate of the basin is of the continental type with a growing season of about 160 days. Precipitation is fairly well distributed throughout the year, although the most occurs in summer and the least in the fall. The mean annual precipitation for the basin varies from about 40 inches in the lower portion to about 45 inches in the upper portion. Mean temperature varies from 36°F in January to 75°F in July with an annual mean of approximately 50°F.

Principal Communities and Industries

There are three major communities in the area. Populations of these towns from 1910 to 1960 are given in Table 3a. Underground coal mining has been the mainstay of the economy, and many of the small industries in the area are support industries for mining.

There is a small agricultural contribution to the economy although the terrain is too steep to permit farming on a large scale. Hay and corn are the main crops on an acreage basis. Perhaps 20 percent of the land in the basin is given over to pasture crops.

Logan and Wyoming counties have some natural gas production.

Big Sandy River Basin

Location and Boundaries

The Big Sandy River Basin is the central basin of the three discussed in this portion of the study. The Big Sandy River is formed by the junction of Tug and Levisa Forks at Louisa, Kentucky, and flows northerly 27 miles to enter the Ohio River about 10 miles downstream from Huntington, West Virginia. It drains 4,280 square miles, of which 2,325 are drained by Levisa Fork and 1,555 by Tug Fork. Levisa Fork rises in southwest Virginia and flows north for 34 miles in Virginia and 130 miles in Kentucky to Louisa. Tug Fork rises in southwestern West Virginia and flows northwest about 60 miles to Kentucky, whence it forms the boundary with West Virginia for about 94 miles. Principal tributaries of Levisa Fork are Russell Fork, Beaver Creek, and Johns Creek, each of which drains more than 200 square miles. On the east, the basin is bounded by the Guyandotte River Basin, on the south by the Tennessee River Basin, and on the west by the Kentucky, Licking and Little Sandy River Basins. Table 1b lists the 17 counties which lie wholly or partly in the basin. Table 2b summarizes pertinent data about the Big Sandy River and its major tributaries.

Physical Features

The Big Sandy River watershed varies from mountainous terrain in its upper portions to hilly areas along Big Sandy River. Slopes of the main stream, Levisa Fork below Russell Fork, and the lower 65 miles of Tug Fork average 1.3 to 2.3 feet per mile.

There is one reservoir in the basin now and three other large scale dams are under construction. Dewey Reservoir on Johns Creek was constructed and is operated by the Corps of Engineers as a unit of the coordinated system for Ohio River Basin flood control. Fishtrap Reservoir on Levisa Fork, John W. Flannagan Reservoir on Pound River, and a reservoir on the North Fork Pound River are presently under construction by the Corps of Engineers. These reservoirs are operated primarily for flood control with some storage designated for quality control.

Climate

A station at Williamson, West Virginia, provides records which indicate generally the climate of the watershed. The average temperature in January is 38°F and in July it is 78°F. Mean annual precipitation

over the 62 years of record was 43.7 inches. The maximum monthly precipitation was 11.9 inches, and the minimum monthly figure was 0.1 inches. The average frost-free period is from April 13 to October 26, 197 days.

Principal Communities and Industries

The largest communities in the Big Sandy River Basin are Williamson, Welch, and War, West Virginia; and Jenkins, Pikeville, Paintsville, and Prestonsburg, Kentucky. Populations of these communities from 1910 to 1960 are given in Table 3b. The principal economic activities are: mining, processing, and transporting of coal; farming; gas and oil production; and lumbering. Corn, potatoes, oats, wheat, tobacco, and hay are the principal crops. Lumbering is of considerable importance in the upper basin.

Little Sandy River Basin

Location and Boundaries

The Little Sandy River Basin is the westernmost of the basins discussed in this section. It is located in northeastern Kentucky and is bounded on the west by Tygarts Creek Basin, on the southwest by Licking River Basin, and on the east by Big Sandy River Basin. The Little Sandy River rises about 6 miles southwest of Sandy Hook, Kentucky, and flows generally northeast 84 miles along a torturous course to its confluence with the Ohio River at Greenup, Kentucky, about 336 miles below Pittsburgh, Pennsylvania. Table 1c presents information about the 6 counties which have a portion of their land area in the Little Sandy Basin. Table 2c gives pertinent data about the major tributaries of the Little Sandy River.

Physical Features

The watershed is similar to the others described in this section, generally hilly to mountainous in its terrain. The Little Sandy valley itself is about 2,000 feet wide below Grayson and about 600 feet wide above Sandy Hook. Between Sandy Hook and Grayson, the river flows about 35 miles through a meandering canyon.

The Grayson Reservoir, now under construction by the Corps of Engineers, will contain runoff from the headwaters region of the basin and be the major body of surface water in the area.

Climate

The climate of this basin is similar to that of the other basins described in this portion of the report.

Principal Communities and Industries

Grayson is the major community in the area. Populations of this city from 1910 to 1960 are given in Table 3c. The principal economic activities are agriculture, manufacturing, mineral production, and lumbering. Clay and limestone are the principal natural resources, and manufacture of refractory products is a major industrial activity. Coal is mined in small quantities, and petroleum is produced in commercial quantities in the extreme southeastern part of the basin. There are also a number of sawmills in the region.

III WATER RESOURCES

Guyandotte River Basin

Surface Water Resources

Quantity

Surface flows are unregulated in the Guyandotte River Basin and there are no natural lakes in the basin. The Guyandotte River has relatively large dry weather flows, probably because the stream crosses permeable geologic formations which consist largely of coarse sandstone interbedded with thin layers of less permeable shale, siltstone, limestone and coal. Dry weather flow in the Mud River is less than in the Guyandotte indicating less permeable formations along its reach. Table 5 shows streamflow data prepared by the Corps of Engineers.[1/]

Quality

Natural quality of the water in the Guyandotte River Basin ranges from moderately hard to hard. Calcium and magnesium hardness ranges from 50 to 250 mg/l. Low flow concentrations of bicarbonate and sulfate are moderately high also with sulfate concentrations ranging from 16 to 260 mg/l. Iron and manganese combined concentrations generally exceed 0.3 mg/l. In addition to natural variations, the entire length of the Guyandotte River and many of its tributaries contain fines discharged from coal washeries. At Logan the turbidity of the water ranges from 10 to 5,000 mg/l.

Ground Water Resources

Quantity

Ground water resources are described by the U. S. Geological Survey[2/] and the following discussion has been condensed from their report.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The southern half of the Guyandotte River Basin is underlain by the permeable sandstone, conglomerate, shale and coal of the Allegheny and Pottsville formations. Water from the sandstones are obtained principally from fractured zones and secondary openings. Deeper wells, 100 to 400 feet in depth, yield 100 to 300 gpm. Wells deeper than this may tap saline water.

Yields to wells in the northern part of the basin are lower, ranging from 20 to 100 gpm. In the Mud River subbasin, the yield to wells is still less, ranging up to 20 gpm. Alluvium along most of the valleys yields enough water for domestic uses only.

Quality

Few data are available regarding the quality of ground water in the basin. Water from wells in the southern half of the basin are usually high in iron and tend to have sulfate concentrations of around 250 mg/l.

Big Sandy River Basin

Surface Water Resources

Quantity

In the Big Sandy River Basin, in the Levisa Fork drainage area, Dewey Reservoir on Johns Creek, constructed by the Corps of Engineers, regulates flood flows and provides low flow supplementation. Three other reservoirs are under construction. Table 4 shows pertinent data regarding these impoundments.

The Tug Fork of the Big Sandy has relatively large, dry weather flows, probably due to the stream crossing permeable geologic formations which consist mainly of coarse sandstone inter-bedded with thin layers of less permeable shale, siltstone, limestone and coal. Dry weather flows in the Levisa Fork of the Big Sandy and in the Big Sandy River are lower, probably due to the presence of extensive shale beds at or near the surface.

Table 5 shows stream data prepared by the Corps of Engineers[1].

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

Quality

Water in the Tug Fork of the Big Sandy River is moderately hard to hard, with calcium and magnesium hardness ranging from 50 to 250 mg/l. Sulfate concentrations in the Tug Fork range from 22 to 386 mg/l. Iron and manganese combined concentrations generally exceed 0.3 mg/l.

Few quality data are available on the Levisa Fork.

Ground Water Resources

Quantity

Ground water resources are reported by the U. S. Geological Survey[1/] and the following discussion has been condensed from their report.

The southern half of the Big Sandy River Basin is underlain by the permeable sandstone, conglomerate, shale and coal of the Allegheny and Pottsville formations. Water from these sandstones is obtained principally from fractured zones and secondary openings. Deeper wells up to 300 feet yield 50 to 200 gpm in the Kentucky portion of the region, and deep wells of 100 to 400 feet yield 100 to 300 gpm in the West Virginia portion of the basin.

Yields to wells in the northern part of the basin range from 20 to 100 gpm. Alluvium along most of the valleys yields enough water for domestic uses only.

Quality

Waters from the southern half of the basin are usually high in iron and tend to have sulfate concentrations of around 250 mg/l, but few data are available beyond this.

Little Sandy River Basin

Surface Water Resources

Quantity

Surface flows are presently unregulated in the Little Sandy River but a reservoir above Grayson, Kentucky, is under construction

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

by the Corps of Engineers and will be operated for flood control and low flow regulation. Table 4 shows pertinent data regarding the aforementioned impoundments. Shown in Table 5 are streamflow data prepared by the Corps of Engineers.[1] Natural dry weather flows in the Little Sandy River are low, but releases from Grayson Reservoir will provide low flow regulation.

Quality

Little information is available but the chemical characteristics of water from the Little Sandy are probably similar to those in the Guyandotte and Big Sandy River Basins.

Ground Water Resources

Quantity

Yields to wells in the Little Sandy River Basin from bedrock formations as reported by the U. S. Geological Survey[2] range from 20 to 100 gpm.

Quality

Little information is available regarding the quality of the ground water in the basin, but water is probably moderately hard to hard and contains undesirable concentrations of iron and manganese.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

IV THE ECONOMY

Approximately one-half of the Guyandotte-Big Sandy-Little Sandy subarea lies in eastern Kentucky and one-half in western West Virginia. Included are the two Virginia counties of Dickenson and Buchanan. To facilitate estimates of future water requirements and waste loads, the subarea has been divided into three minor areas, J-1, J-2, and J-3. The J-1 area includes the northern two counties encompassing the upper reaches of Tygarts Creek, considered as main stem drainage, and the Little Sandy River. The J-2 area is roughly coextensive with the watershed of the Levisa Fork of the Big Sandy River and the upper reaches of the Tug Fork of the Big Sandy River and encompasses five counties in Kentucky, two in Virginia and one in West Virginia. J-3 contains the middle and upper reaches of the Guyandotte River and encompasses four West Virginia counties. The counties in each area are listed in Tables 6 and 7 and shown on Figure 6-1, page 6-53. The entire subarea lies in the area designated as Appalachia.

Economic Profiles

Minor Area J-1

Population decreased 8.8 percent between 1950 and 1960, to 27,100 in 1960 in this sparsely settled area. Average per capita personal income at $812 is well below the $1,322 average for Kentucky. The largest community in the basin is Grayson with a population of 1,700.

Manufacturing is the most important employment category. The area had five establishments hiring over 100 employees in 1964. The most important employment industries are other durables, printing and publishing, furniture and wood products, and primary metals.

Agricultural employment declined at an average annual rate of 8.1 percent between 1950 and 1960. However, the total value of farm products sold in 1959 remained at about the 1954 level of $3.7 million. Seventy-eight percent of the total value was derived from the sale of field crops. Less than 20 acres were irrigated in 1959.

The most important mining categories in 1960 were coal, crude oil, and clay production. Of the three, clay extraction predominated with 203,000 tons produced equaling 21 percent of the total production in Kentucky. Coal and oil activity were relatively less important, 36,000 tons and 93,000 barrels being produced respectively, both representing less than one percent of total State production.

Minor Area J-2

The population in minor area J-2 was 280,300 in 1960. Average per capita income was well below the average of that for Kentucky, being $867 and $1,322 respectively. Figures taken from the same source give average per capita income for the Nation as $1,850. The largest community in this minor area is Pikeville with a population of over 4,700.

Mining is by far the most important employment category. Forty-one percent of total employment was engaged in mining in 1960. Coal production reached 12.3 million tons in that year and 579,400 barrels of crude oil were extracted.

Manufacturing is limited to small and dispersed establishments, the area having no plants in 1964 hiring as many as 100 employees. The most important employment industries were furniture and wood products, food processing, printing and publishing, and machinery (including electrical machinery). One thermal electrical plant is located in Lawrence County with 265 megawatt generating capacity.

Agricultural employment fell from 9,900 in 1950 to 1,700 in 1960, and 250,000 acres were taken out of farm production between 1954 and 1959. The total value of farm products sold between 1954 and 1959, however, has been maintained at about the 1959 figure of $3.4 million. Field crops and livestock products each accounted for about half of the total. Less than 200 acres were irrigated.

Minor Area J-3

Total population in 1960 amounted to 156,400 in this minor area. Average per capita income was $1,055 as compared to $1,378 for West Virginia. The largest community in the area is Williamson with a population of just over 6,700.

Mining is the most important employment category, and practically all activity is confined to coal and gas extraction. In 1960, 32.9 million tons of coal were produced equaling 27.7 percent of total production in West Virginia. Production data on gas and oil are not available, but data on the number of drilled wells are available. In 1963, three producing oil wells and 51 producing gas wells were drilled. In West Virginia as a whole, at this time, 97 producing oil wells, 641 producing gas wells and 219 combination gas and oil wells were completed.

Manufacturing is characterized by small and dispersed plants, none of which employed 100 workers or more. The most important employment industries are furniture and wood products, food processing, machinery (including electrical machinery), and printing and publishing.

Agricultural employment declined 76.9 percent between 1950 and 1960, and 105,000 acres were taken out of production between 1954 and 1959. Even so, the total value of farm products sold has remained at approximately the 1954 figure of $1.2 million. Less than 50 acres were irrigated in 1959.

Projected Population and Industrial Activity

Population of the Guyandotte-Big Sandy-Little Sandy subarea, according to the Projective Economic Study, is expected to decrease from 463,800 in 1960 to 401,300 by 1980 and to 355,000 by 2020. This represents a decrease in the subarea's share of Ohio River Basin population from 2.4 percent in 1960 to 1 percent by 2020.

Table 6 shows the base and projected populations for the J-1, J-2 and J-3 minor areas.

Manufacturing output is expected to increase from $139.3 million in 1960 to $598.9 million in 2010, while agricultural output is projected to decrease from $40.1 million in 1960, to $29 million by 1980 to $1.9 million by 2010.

Table 7 shows 1960 output, total employment, and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

Since this entire subarea is in the area designated as Appalachia, covered by the Appalachian Regional Redevelopment Act of 1965 (PL 89-4), these projections will be subject to review based on the findings of the Appalachian Regional Commission survey currently underway.

In addition to the counties included in Guyandotte-Big Sandy-Little Sandy subarea in the Projective Economic Study, other counties have land areas within the respective basins. These counties are listed in Tables 8a, 8b and 8c for the three separate drainage areas.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Guyandotte River Basin

Present and Projected Water Use

There are 66 central water supply systems in the Guyandotte River Basin, serving a population of 60,000. The average daily water use is 4.8 mgd, amounting to 80 gallons per capita daily use.

In the basin, the amount of water used for municipal supplies is very nearly equally divided between ground and surface sources. The largest water use is recorded in Logan County, West Virginia, accounting for almost 60 percent of the total water use in the basin. The largest municipal supply in the basin is located in this county at Logan, West Virginia, serving 15,270 people, with an average daily use of 1.200 mgd and accounting for about 25 percent of the total water use in the basin. The remaining municipal systems, while numerous are relatively small, none serving more than 5,000 people with the principal source of supply being obtained from ground sources, either from active mines, inactive mines or wells.

In the lower basin, the largest municipal water system is at Milton in Cabell County, West Virginia, on the Mud River serving 2,500 people. The present municipal and industrial water use in the basin is listed by county and totaled for economic subareas and other areas in the basin in Table 9a.

Based on population trends and projected industrial activity, estimated water use will increase in the Guyandotte River Basin as shown in Table 10a. It is estimated that total municipal and industrial requirements will increase only slightly by 2020. In minor area J-3, it is estimated that population served will decrease, with the average daily water use remaining fairly constant during the projection period. In other areas in the basin, total water use is projected to increase over 2.5 times, but the total water use by 2020 is estimated to be but 2.7 mgd.

Water Supply Problems

The projected total water supply figures shown in Table 10a, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply.

In the upper and middle portions of the basin south of the Logan-Lincoln county line, ground water from bedrock formations while of inferior quality is plentiful and surface supplies appear to be adequate to meet foreseeable municipal and industrial needs. In the lower basin, one municipality, Milton, located on the Mud River, a tributary of the Guyandotte River, serves 2,500 people from a surface source. Ground water is present in only small quantities in bedrock formation but surface supplies have evidently been adequate in the past and only moderate growth is projected for the area. However, increased per capita use will probably increase the demand for water. This does not appear to be a serious problem area and offstream storage could provide additional supply during periods when streamflows are low.

Big Sandy River Basin

Present and Projected Water Use

There are 110 central water supply systems in the Big Sandy River Basin, serving a population of 122,000. The average daily water use is 11.0 mgd, amounting to 90 gallons per capita daily use. The present municipal and industrial water use in the basin is listed by county and totaled by economic subareas and other areas in the basin in Table 9b.

In the basin, the source of water for municipal supplies is about equally divided between ground and surface sources. The largest water use is in McDowell County, West Virginia in the upper basin, drained by the Tug Fork. This county accounts for almost 66 percent of the total water use in the basin. While water systems are numerous, only one system (War, West Virginia) serves as many as 4,500 people. One of the larger municipal systems is located at Williamson, West Virginia, on the Tug Fork serving a population of 8,750. On

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

Levisa Fork, Paintsville in Johnson County, Kentucky serves about 6,700 people and Pikeville in Pike County, Kentucky serves almost 6,000 people.

Catlettsburg, Kentucky, serving 10,000 people is located in the lower basin and has the largest water system in the basin in terms of population served. The major industrial water use occurs also in this reach of stream.

Based on population trends and projected industrial activity, estimated water use will increase in the Big Sandy River Basin as shown in Table 10b. It is estimated that total municipal and industrial water requirements will triple by 2020. The major increases will probably occur in or about the present centers in population and industrial activity.

In minor area J-2, water use is projected to increase less than twice by 2020. In minor area J-3, no increase is projected in water use by 2020. In other areas in the basin, total water use is projected to increase about 3.5 times. Most of this increase will be industrial use in the lower Big Sandy River.

Water Supply Problems

The projected total water supply figures shown in Table 10b, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply.

In the middle and upper reaches of Tug and Levisa Fork, south of the north boundary line of Logan and Mingo Counties in West Virginia and Martin and Floyd Counties in Kentucky, ground water resources in the bedrock formations appear to be adequate to satisfy future needs. At the present time, water supplies in this portion of the basin represent 85 percent of the total municipal water use in the basin. North of the aforementioned line, ground water is considered to have less potential as a source of supply for municipal and industrial needs. The larger communities in the Levisa Fork drainage area are Paintsville and Prestonsburg serving populations of 6,700 and 4,700 respectively. These communities use surface water from Levisa Fork and supply appears to adequately meet future needs.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

Catlettsburg obtains its supply from the lower reach of the Big Sandy River in pool from Greenup Dam and should not experience a shortage of water although recently problems have been reported regarding raw water quality.

Little Sandy River Basin

Present and Projected Water Use

There are only two central water supply systems in the Little Sandy River Basin serving 3,105 persons. The average daily water use is 0.225 mgd, amounting to 73 gallons per capita daily use. The present municipal and industrial water use in the basin is listed by county and totaled for economic subareas and other areas in the basin in Table 9c.

In the basin, nearly 90 percent of the municipal water use is obtained from a surface source by Grayson, Kentucky, the largest water using community in the basin.

Based on population trends and projected industrial activity, estimated water use will increase in the Little Sandy River Basin as shown in Table 10c. It is estimated that total municipal and industrial water requirements will double by 2020.

Water Supply Problems

The projected total water supply figures shown in Table 10c, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to need of future development of sources of water supply.

Grayson, presently using surface water from the Little Sandy River as its source of supply, has a supply of raw water barely adequate to meet future needs. Should industrial needs develop in this area, offstream storage may be required to meet this need since ground water in the area is not a dependable source. An alternate source of additional water supply could be found in Grayson Reservoir, a Federal multipurpose project, if storage can be reallocated.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11

GUYANDOTTE-BIG SANDY-LITTLE SANDY RIVER BASINS

Water Supply Problem Areas

Minor Area	Present	1980	2000	2020

No problem areas within the scope of this study.

VI WATER QUALITY CONTROL

Guyandotte River Basin

Present and Projected Waste Loads

Present organic waste loads generated are shown in Table 12a. The larger sources of municipal waste discharges occur at Logan, on the middle main stem, Mullens in the headwaters and Milton on the lower reaches of the Mud River. Most of the smaller communities are not sewered and therefore organic waste loads generated in these communities are not shown in Table 12a. However, if these communities are eventually sewered there could be significant increases in organic wastes to the streams without increases in population.

Shown in Table 13a are the base and projected waste loads generated for the minor area. Municipal waste loads generated are projected to decline in the basin but will be offset by an increase in industrial organic waste loads resulting in a slight increase in total organic waste loads by 2020.

Water Quality Control Problems

The major water quality control problems in the basin are related to coal mining operations, primarily fines and silt from coal washing. Progress is being made through efforts of the West Virginia State Water Resources Commission and cooperation of mining companies in reducing coal washery waste pollution. Removal of these wastes can be accomplished by proper construction and operation of sedimentation facilities and proper storage of removed solids to prevent washing out during periods of heavy rainfall.

The larger source of organic wastes from community sewage discharges occurs at Logan. At the present, the sewered population is about 5,000 people. However, in the immediate vicinity, over 15,000 people are served by the Logan central water system. If all these people were served by sewers and secondary treatment of wastes are performed, the design flow of 18 cfs is adequate to assimilate the residual wastes. However, if one "wet" industry utilizing the timber resources of the area located in this vicinity, flows in the

order of 50 to 100 cfs would be needed to assimilate treated wastes from this type of industry. In addition, this flow would insure a higher quality water in lower reach of Guyandotte River in the pool from Greenup Dam, by providing sufficient velocity for continued movement of residual wastes from upstream sources and uncollectable wastes entering the stream along this reach.

In addition to the coal washery wastes discussed previously, another quality problem is mine drainage pollution in many of the headwater streams.

Big Sandy River Basin

Present and Projected Waste Loads

Present organic waste loads generated are shown in Table 12b. Organic waste loads are discharged to the Tug Fork and tributaries by communities in McDowell and Mingo Counties, West Virginia and to the Levisa Fork and tributaries in Buchanan County, Virginia and Pike and Letcher Counties, Kentucky. Many of the smaller communities with central water supply systems are not sewered and therefore organic waste loads generated by these communities do not appear in Table 12b.

Shown in Table 13b are base and projected waste loads generated for the minor areas. Total organic waste loads generated are projected to decline generally in the basin with the municipal waste load decrease not being entirely offset by increased organic waste loads generated by industrial activity.

Water Quality Control Problems

With the completion of high level dams on the Ohio River, favorable conditions for industrial development now exist in the lower 15 miles of the Big Sandy River.

The major water quality control problem in the basin is in the Big Sandy River below Louisa, Kentucky, and primarily in the reach of the river in pool from Greenup Dam. It has been noted in the past year that during periods of low flow in the Big Sandy River, the city of Catlettsburg, withdrawing water from this reach, has experienced taste and odor problems caused by nutrients in the water promoting algal growths at lower flows. These nutrients are reaching the stream

as residuals from upstream sources by surface runoff. Uncollectable wastes such as storm water overflows from combined sewers and street washings, enter the stream along this reach. In order to assure a higher quality of water in this reach of stream, where the design flow is 79 cfs, by providing sufficient velocity for continued movement of residual wastes and uncollectable wastes, total flow in the order of 380 cfs will be needed by 1980, increasing to about 525 cfs in 2000, and to 550 cfs by 2020.

The largest community in the Tug Fork subdrainage basin is Williamson, West Virginia, where the design flow is about 25 cfs. This streamflow is sufficient to meet the needs for assimilation of residual organic wastes discharged after secondary treatment. However, assuming a moderate increase in industrial activity to make use of the surplus labor in the Williamson area assured total flows in the order of 40 cfs would be needed.

In the Levisa Fork subbasin, the 1960 population in each of the communities of Paintsville, Prestonsburg and Pikeville is less than 5,000. Design streamflows are capable of assimilating residual wastes discharged to the stream at these points after secondary treatment by the communities. However, should a single "wet industry," such as a 200 ton per day pulp plant locate on Levisa Fork, flows in the order of 200 cfs would be needed to assimilate treated wastes discharged to the stream. Considering the timber resources in the area this is a feasible industrial development.

Other present or potential quality problems are heat, fines from coal washing and mine drainage. The major source of heat release to a stream in the basin is from a thermal power generating plant located near Louisa, Kentucky, having a capacity of 265 megawatts. This plant uses surface water as a source of cooling water and during periods of low flow causes high stream temperatures downstream in a localized stream reach. Coal mining is a major industry in the upstream reaches of the basin and many streams are affected by mine drainage and fines from coal washing operations. Due to efforts of the States in the basin, mine operators are improving the handling of coal fines. Continuing pressure by Virginia, West Virginia, and Kentucky agencies should be exerted to eliminate the coal fine problem. Coal fine discharges to the streams usually result from carelessness by the operators.

Little Sandy River Basin

Present and Projected Waste Loads

Present organic waste loads generated are shown in Table 12c. There is only one community in the basin collecting and discharging sanitary sewage to the streams of the basin. Shown in Table 13c are the base and projected organic waste loads generated for the portion of the minor area included in the Little Sandy River Basin. Total waste loads generated are projected to increase slightly by 2020.

Water Quality Control Problems

Design streamflow should be sufficient to assimilate projected residual waste loads discharged after secondary treatment.

Coal mining is an industry in minor area J-1, but is not a source of serious stream pollution.

TABLE 14

GUYANDOTTE-BIG SANDY-LITTLE SANDY RIVER BASINS

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date			
			Present	1980	2000	2020

No problem areas within the scope of this study.

TABLES

TABLE 1a

GUYANDOTTE RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
West Virginia		Boone	13.9
" "		Cabell	65.1
" "	*	Lincoln	85.2
" "	*	Logan	86.3
" "	*	Mingo	14.1
" "		Putnam	22.7
" "		Raleigh	16.3
" "	*	Wyoming	100.0

*Counties considered in Projective Economic Study of Guyandotte River Basin.

TABLE 2a

GUYANDOTTE RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Guyandotte River	1,671	167	0
Mud River	358	79	7

TABLE 3a

GUYANDOTTE RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Logan	Logan	West Va.	1,640	2,998	4,396	5,166	5,079	4,185
Mullens	Wyoming	" "	-	1,425	2,356	3,026	3,470	3,544
Mount Gay 1/	Logan	" "	-	-	-	-	-	3,386

1/ Unincorporated

TABLE 1b

BIG SANDY RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky		Boyd	26.9
Virginia	*	Buchanan	100.0
"	*	Dickenson	100.0
Kentucky	*	Floyd	100.0
"	*	Johnson	100.0
"		Knott	28.2
"	*	Lawrence	91.5
"		Letcher	6.5
West Virginia	*	McDowell	100.0
Kentucky		Magoffin	4.1
"	*	Martin	100.0
West Virginia	*	Mingo	73.3
Kentucky		Morgan	10.1
"	*	Pike	100.0
Virginia		Tazewell	11.0
West Virginia		Wayne	23.4
Virginia		Wise	28.1

*Counties considered in Projective Economic Study of Big Sandy River Basin.

TABLE 2b

BIG SANDY RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Big Sandy River	4,280	27	0
Tug Fork	1,555	154	27
Levisa Fork	2,325	164	27
Russell Fork*	679	45	127
Beaver Creek*	240	27	92
Johns Creek*	224	64	74

*Included with Levisa Fork drainage area.

TABLE 3b

BIG SANDY RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Williamson	Mingo	West Va.	3,561	6,819	9,410	8,366	8,624	6,746
Welch	McDowell	" "	1,526	3,232	5,376	6,264	6,603	5,313
Pikeville	Pike	Kentucky	1,280	2,110	3,376	4,185	5,154	4,754
Paintsville	Johnson	"	942	1,383	2,411	2,324	4,309	4,025
Jenkins	Letcher	"	-	4,707	8,465	9,428	6,921	3,202
Prestonsburg	Floyd	"	-	-	-	2,328	3,585	3,133
War	McDowell	West Va.	-	-	1,392	1,277	3,992	3,006

TABLE 1c

LITTLE SANDY RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky		Boyd	52.9
"	*	Carter	58.1
"	*	Elliott	96.4
"		Greenup	35.3
"	*	Lawrence	8.5
"		Rowan	6.0

*Counties considered in Projective Economic Study of Little Sandy River Basin.

TABLE 2c

LITTLE SANDY RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Little Sandy River	721	84	0
East Fork	151	48	12
Little Fork	132	35	41

TABLE 3c

LITTLE SANDY RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Grayson	Carter	Kentucky	735	822	1,022	1,176	1,383	1,692

TABLE 4

GUYANDOTTE-BIG SANDY-LITTLE SANDY RIVER BASINS

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Seasonal Pool Area (Acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Guyandotte River					
None					
Big Sandy River					
Dewey	F	1,100	76,100		17,200 2/
Fishtrap 1/	F, A	1,130	126,640		37,720 3/
John W. Flannagan 1/	F, A, R	1,140	78,600		67,100 4/
North Fork of Pound 1/	F, R	154	8,109		3,184 5/
Little Sandy River					
Grayson 1/	F, A, R	1,500	100,250		29,390 6/
Greenbo	R	225			

F - Flood Control
R - Recreation
A - Low Flow Regulation

1/ Under Construction.
2/ 4,900 acre-feet of this low flow augmentation, seasonal.
3/ 27,190 acre-feet of this low flow augmentation, seasonal.
4/ 38,600 acre-feet Water Quality Control; 16,500 acre-feet low flow augmentation, seasonal.
5/ 1,290 acre-feet of this low flow augmentation, seasonal.
6/ 13,940 acre-feet of this low flow augmentation, seasonal.

TABLE 5

GUYANDOTTE, BIG SANDY, LITTLE SANDY RIVER BASINS

Flow Data 1/

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Guyandotte River						
Branchland, W. Va.	1,226	1,573	3.6	40,400	20	10.3
Big Sandy River						
Louisa, Ky.	3,870	4,228		89,400	59	29
Levisa Fork						
Pikeville, Ky.	1,237	1,353	1.5	85,500	3.9	1.4
Paintsville, Ky.	2,143	2,385	8.4	69,700	15	7
Tug Fork						
Litwar, W. Va.	502	529	11	35,700	21	13.8
Kermit, W. Va.	1,185	1,332	23	61,300	26	15.4
Little Sandy River						
Grayson, Ky.	402	484	1.5	24,500	2.7	0.7

1/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey."

TABLE 6

GUYANDOTTE-BIG SANDY-LITTLE SANDY RIVER BASINS

Economic Subarea J
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation J-1									
Kentucky	Carter	20,800	0						
"	Elliott	6,300	0						
	Subtotal	27,100	0	28,900		28,300		28,000	
Area Designation J-2									
Virginia	Buchanan	36,700	0						
"	Dickenson	20,200	0						
Kentucky	Floyd	41,600	3,100						
"	Johnson	19,700	4,000						
"	Lawrence	12,100	0						
West Va.	McDowell	71,400	8,300						
Kentucky	Martin	10,200	0						
"	Pike	68,400	4,800						
	Subtotal	280,300	20,200	244,400		234,400		224,000	
Area Designation J-3									
West Va.	Lincoln	20,300	0						
"	Logan	61,600	7,600						
"	Mingo	39,700	6,700						
"	Wyoming	34,800	3,500						
	Subtotal	156,400	17,800	128,000		115,000		103,000	
Total Subarea J		463,800	38,000	401,300	33,000	377,700	30,800	355,000	29,000

TABLE 7

GUYANDOTTE-BIG SANDY-LITTLE SANDY RIVER BASINS

Economic Subarea J
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation J-1													
Kentucky	Carter	5,100	1,710										
"	Elliott	1,300	140										
	Subtotal	6,400	1,850	29.1	126	102	158	155	112	263	188	123	451
Area Designation J-2													
Virginia	Buchanan	8,500	390										
"	Dickenson	4,300	220										
Kentucky	Floyd	8,200	280										
"	Johnson	4,200	220										
"	Lawrence	2,400	280										
"	Martin	1,600	170										
"	Pike	13,200	750										
West Va.	McDowell	15,200	510										
	Subtotal	57,600	2,820	59.1	110	117	198	132	130	422	169	146	710
Area Designation J-3													
West Va.	Lincoln	3,700	740										
"	Logan	13,800	810										
"	Mingo	7,400	440										
"	Wyoming	7,700	410										
	Subtotal	32,600	2,400	51.1	102	107	158	118	117	232	138	129	286
Total Subarea J		96,600	7,070	139.3	108	109	175	129	121	313	160	134	518

*In millions of 1960 dollars.
**1960 = 100

TABLE 8a

GUYANDOTTE RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
West Virginia	Boone	G-5	Kanawha-Little Kanawha
" "	Cabell	H-2	Ohio-Huntington
" "	Putnam	G-1	Kanawha-Little Kanawha
" "	Raleigh	G-5	Kanawha-Little Kanawha

TABLE 8b

BIG SANDY RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Boyd	H-2	Ohio-Huntington
"	Knott	M-4	Licking-Kentucky-Salt
"	Letcher	M-4	Licking-Kentucky-Salt
"	Magoffin	M-3	Licking-Kentucky-Salt
"	Morgan	M-3	Licking-Kentucky-Salt
Virginia	Tazewell	*	
West Virginia	Wayne	H-2	Ohio-Huntington
Virginia	Wise	*	

* - Not included in Projective Economic Study of Ohio River Basin.

TABLE 8c

LITTLE SANDY RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Boyd	H-2	Ohio-Huntington
"	Greenup	H-1	Ohio-Huntington
"	Rowan	M-3	Licking-Kentucky-Salt

TABLE 9a

GUYANDOTTE RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation J-3											
West Va.	Lincoln	1	1,200	1,200		.070	.070		58	Well	0
"	Logan	27	32,500	11,330	21,170	2.842	1.208	1.634	87	Guyandotte R., Buffalo Crk., Wells, Mines	0.1
"	Mingo	1	875		875	.061		.061	70	Guyandotte River	0
"	Wyoming	20	14,900	10,700	4,200	.968	.726	.242	65	Laurel Fk., Pinnacle Crk., Mines, Wells	0
	Subtotal	49	49,475	23,230	26,245	3.941	2.004	1.937	80		0.1
Other Areas in Basin											
West Va.	Cabell	1	2,500		2,500	.150		.150	60	Mud River	0.1
"	Raleigh	16	8,275	8,275		.752	.752		91	Wells, Mines	0
	Subtotal	17	10,775	8,275	2,500	.902	.752	.150	84		0.1
	TOTAL	66	60,250	31,505	28,745	4.843	2.756	2.087	80		0.2

Note: For Area Designation J-2 see Big Sandy River Basin.
For Area Designation J-1 see Little Sandy River Basin.

TABLE 10a

GUYANDOTTE RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation J-3												
From Central Supplies	49,475	80	3.9	40,600	92	3.7	36,600	102	3.7	33,100	112	3.7
Industrial			0.1			0.1			0.2			0.2
Subtotal			4.0			3.8			3.9			3.9
Other Areas in Basin												
From Central Supplies	10,775	84	0.9	12,700	95	1.2	14,400	105	1.5	19,700	115	2.3
Industrial			0.1			0.2			0.3			0.4
Subtotal			1.0			1.4			1.8			2.7
Guyandotte River Basin												
From Central Supplies Total	60,250	80	4.8	53,300	92	4.9	51,000	102	5.2	52,800	114	6.0
Industrial Total			.2			0.3			0.5			0.6
GRAND TOTAL			5.0			5.2			5.7			6.6

TABLE 9b

BIG SANDY RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation J-2											
Virginia	Buchanan	8	4,050	4,050		.270	.270		67	Wells, Spring	0
"	Dickenson	4	3,200	3,200		.255	.255		80	Wells	0
Kentucky	Floyd	10	15,650	3,610	12,040	1.028	.256	.772	66	Big Sandy R., Levisa Fk., Beaver Creek Mines, Wells	1.0
"	Johnson	2	8,580		8,580	.480		.480	56	Big Sandy River, Levisa Fork	0
"	Lawrence	1	3,100		3,100	.190		.190	61	Levisa Fork	0
West Va.	McDowell	52	48,050	40,735	7,315*	4.472	3.592	.880	93	Tug Fork, Mines, Wells, Springs	0.1
Kentucky	Martin	0									0
"	Pike	15	12,545	2,155	10,390*	1.077	.159	.918	86	Levisa Fk., Russell Fk., Mines, Wells	0
	Subtotal	92	95,175	53,750	41,425	7.772	4.532	3.240	82		1.1
Area Designation J-3											
West Va.	Lincoln	0									0
"	Logan	0									0
"	Mingo	15	15,170	3,380	11,790	2.042	.592	1.450	135	Tug Fork, Wells, Mine	0
"	Wyoming	0									0
	Subtotal	15	15,170	3,380	11,790	2.042	.592	1.450	135		0
Other Areas in Basin											
Kentucky	Boyd	1	10,000		10,000	1.000		1.000	100	Big Sandy River	50.0
"	Letcher	1	1,000	1,000		.070	.070		70	Wells	0
Virginia	Wise	1	1,150		1,150	.100		.100	87	Mountain Watershed and Wells	0
	Subtotal	3	12,150	1,000	11,150	1.170	.070	1.100	99		50.0
	TOTAL	110	122,495	58,130	64,365	10.984	5.194	5.790	90		51.1

Note: For Area Designation J-1 see Little Sandy River Basin.

*Combined Supplies

TABLE 10b

BIG SANDY RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation J-2												
From Central Supplies	95,175	82	7.8	82,800	94	7.8	80,000	103	8.2	75,200	114	8.6
Industrial			1.1			1.7			3.0			4.7
Subtotal			8.9			9.5			11.2			13.3
Area Designation J-3												
From Central Supplies	15,170	135	2.0	12,400	149	1.9	11,200	160	1.8	10,200	165	1.7
Industrial			0			0.1			0.2			0.3
Subtotal			2.0			2.0			2.0			2.0
Other Areas in Basin												
From Central Supplies	12,150	99	1.1	14,000	110	1.5	16,800	120	2.0	21,200	130	2.8
Industrial			50.0			71.5			108.0			170.0
Subtotal			51.1			73.0			110.0			172.8
Big Sandy River Basin												
From Central Supplies Total	122,495	90	10.9	109,200	103	11.2	108,000	111	12.0	106,400	123	13.1
Industrial Total			51.1			73.3			111.2			175.0
GRAND TOTAL			62.0			84.5			123.2			188.1

TABLE 9c

LITTLE SANDY RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served			Average Municipal Water Use (mgd)			Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
			Total	From Ground	From Surface	Total	From Ground	From Surface			
Area Designation J-1											
Kentucky	Carter	1	2,680		2,680	.190		.190	71	Little Sandy River	0.1
"	Elliott	1	425	425		.035	.035		82	Wells	0
	TOTAL	2	3,105	425	2,680	.225	.035	.190	73		0.1

Note: For Area Designation J-3 see Big Sandy and Guyandotte River Basins.
For Area Designation J-2 see Big Sandy River Basin.

TABLE 10c

LITTLE SANDY RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation J-1												
From Central Supplies	3,105	73	0.2	3,300	89	0.3	3,200	98	0.3	3,150	109	0.3
Industrial			0.1			0.1			0.2			0.3
Subtotal			0.3			0.4			0.5			0.6
Little Sandy River Basin												
From Central Supplies Total	3,105	73	0.2	3,300	89	0.3	3,200	98	0.3	3,150	109	0.3
Industrial Total			0.1			0.1			0.2			0.3
GRAND TOTAL			0.3			0.4			0.5			0.6

TABLE 12a

GUYANDOTTE RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*: Domestic & Commercial	Estimated Industrial
Area Designation J-3						
West Va.	Lincoln	1	950	Mud River	950	200
"	Logan	2	6,000	Guyandotte River, Buffalo Creek	6,000	1,200
"	Mingo	0	0		0	0
"	Wyoming	3	5,985	Slab Fork, Clear Fork, Guyandotte River	5,985	0
	Subtotal	6	12,935		12,935	1,400
Other Areas in Basin						
West Va.	Cabell	2	2,050	Mud River	2,050	400
	Subtotal	2	2,050		2,050	400
	TOTAL	8	14,985		14,985	1,800

*NOT to be interpreted as waste loads to the stream.

TABLE 13a

GUYANDOTTE RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation J-3				
Domestic and Commercial	12,935	10,600	9,600	8,700
Industrial	1,400	1,800	2,400	2,900
Subtotal	14,335	12,400	12,000	11,600
Other Areas in Basin				
Domestic and Commercial	2,050	2,600	3,100	3,900
Industrial	400	600	900	1,400
Subtotal	2,450	3,200	4,000	5,300
Guyandotte River Basin				
Domestic and Commercial Total	14,985	13,200	12,700	12,600
Industrial Total	1,800	2,400	3,300	4,300
GRAND TOTAL	16,785	15,600	16,000	16,900

*NOT to be interpreted as waste loads to the stream.

TABLE 12b

BIG SANDY RIVER BASIN

Base Municipal and Industrial Organic Waste **Production**

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation J-2						
Virginia	Buchanan	4	5,240	Levisa Fork	5,240	0
"	Dickenson	1	1,400	Holly Creek	1,400	200
Kentucky	Floyd	4	6,910	Levisa Fk.,Otter Crk.,Rt.Fk.Beaver Crk.	6,910	200
"	Johnson	1	4,025	Paint Creek	4,025	400
"	Lawrence	1	2,070	Big Sandy River	2,070	0
West Va.	McDowell	9	14,865	Elkhorn Crk., Tug Fork, Dry Fork	14,865	300
Kentucky	Martin	0	0		0	0
"	Pike	2	5,840	Levisa Fork, Russell Fork	5,840	600
	Subtotal	22	40,350		40,350	1,700
Area Designation J-3						
West Va.	Lincoln	0	0		0	0
"	Logan	0	0		0	0
"	Mingo	4	9,010	Tug Fork, Pigeon Creek	9,010	600
"	Wyoming	0	0		0	0
	Subtotal	4	9,010		9,010	600
Other Areas in Basin						
Kentucky	Letcher	1	3,200	Elkhorn Creek	3,200	0
	Subtotal	1	3,200		3,200	0
	TOTAL	27	52,560		52,560	2,300

Note: For Area Designation J-1 see Little Sandy River Basin.

***NOT** to be interpreted as waste loads to the stream.

TABLE 13b

BIG SANDY RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation J-2				
Domestic and Commercial	40,350	35,100	33,900	31,900
Industrial	1,700	2,700	4,700	7,300
Subtotal	42,050	37,800	38,600	39,200
Area Designation J-3				
Domestic and Commercial	9,010	7,400	6,700	6,000
Industrial	600	800	1,000	1,200
Subtotal	9,610	8,200	7,700	7,200
Other Areas in Basin				
Domestic and Commercial	3,200	2,600	2,400	2,100
Industrial	0	100	200	200
Subtotal	3,200	2,700	2,600	2,300
Big Sandy River Basin				
Domestic and Commercial Total	52,560	45,100	43,000	40,000
Industrial Total	2,300	3,600	5,900	8,700
GRAND TOTAL	54,860	48,700	48,900	48,700

*NOT to be interpreted as waste loads to the stream.

TABLE 12c

LITTLE SANDY RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*: Domestic & Commercial	Estimated Industrial
Area Designation J-1						
Kentucky	Carter	1	1,690	Little Sandy River	1,690	0
"	Elliott	0	0		0	0
	Subtotal	1	1,690		1,690	0
	TOTAL	1	1,690		1,690	0

Note: For Area Designation J-3 see Big Sandy and Guyandotte River Basins.
For Area Designation J-2 see Big Sandy River Basin.

*NOT to be interpreted as waste loads to the stream.

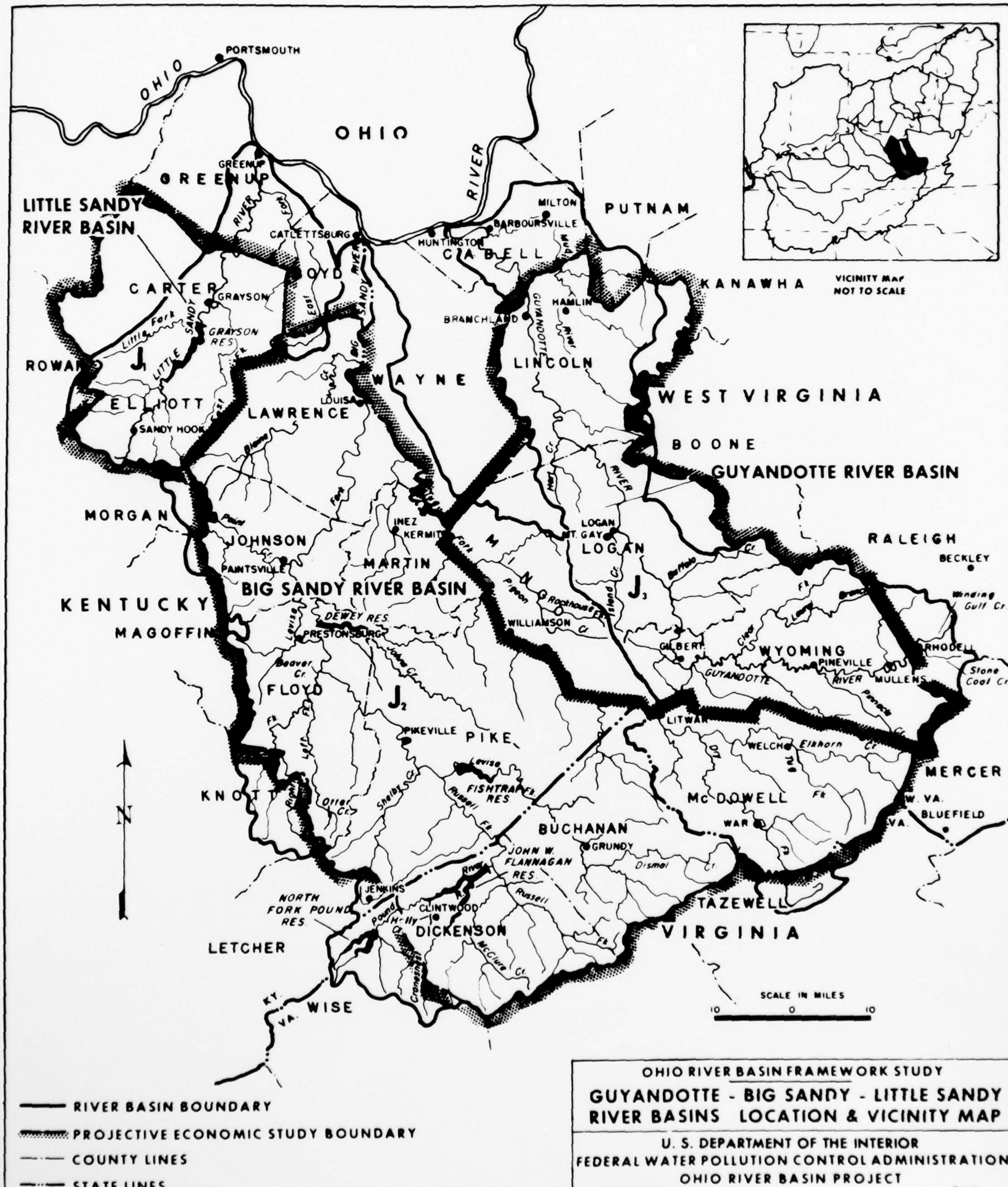
TABLE 13c

LITTLE SANDY RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation J-1				
Domestic and Commercial	1,690	1,800	1,800	1,700
Industrial	0	100	200	300
Subtotal	1,690	1,900	2,000	2,000
Little Sandy River Basin				
Domestic and Commercial Total	1,690	1,800	1,800	1,700
Industrial Total	0	100	200	300
GRAND TOTAL	1,690	1,900	2,000	2,000

*NOT to be interpreted as waste loads to the stream.



OHIO RIVER BASIN FRAMEWORK STUDY

GUYANDOTTE - BIG SANDY - LITTLE SANDY RIVER BASINS LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 6 1

SCIOTO RIVER BASIN

Subbasin Area
No. 7

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I SUMMARY

Municipal and Industrial Water Supply Problems

The major municipal water use in the Scioto River Basin is at Columbus, Ohio, and indications are that by 1980 additional sources of supply must be available to satisfy projected water supply needs. The major industrial water use in the basin is in the Chillicothe-Circleville area, where the projected needs can probably be satisfied from underground sources. The municipality of Greenfield has experienced supply problems with a ground water source and is planning to develop its source of supply in a proposed Federal reservoir. The municipalities of Marion, Galion, Hillsboro, Westerville, West Jefferson, and Washington Court House must develop additional sources of supply by 1980 to satisfy projected water supply demands. Other communities such as Hilliard, Reynoldsburg, Sabina, Chillicothe, Circleville, and Kenton will probably encounter problems with supply by 2000. London will probably encounter problems with supply by 2020.

Water Quality Control Problems

The major problem area in the Scioto River Basin occurs in the Scioto River below Columbus, Ohio. Even with secondary treatment of organic wastes by the city of Columbus, present critical low summer flows in the Scioto River are not sufficient to assimilate residual organics discharged to the stream without degradation of water quality. This condition will worsen under projected population growth and industrial activity.

The major industrial activity resulting in the discharge of organic wastes occurs at Chillicothe. Assuming treatment of industrial organic waste equivalent to secondary treatment of municipal organic wastes, the provision of adequate flows in the Scioto River at Columbus will maintain satisfactory conditions at Chillicothe.

Stream conditions are unsatisfactory in Alum Creek below Westerville, Little Scioto River below Marion, the Olentangy below Galion and Paint Creek below Washington Court House. In addition, many of the smaller tributaries have unsatisfactory conditions due to residual organic waste discharges from communities.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Scioto River Basin lies in the central portion of the State of Ohio, its eastern limits nearly coinciding with the north-south center line of the State, and forms the principal drainage system of central Ohio. The Scioto River rises in northwestern Ohio, flows east 60 miles where it is joined by the Little Scioto, then south 175 miles where it enters the Ohio River at Portsmouth, Ohio, 356 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is 6,510 square miles, comprising about 16 percent of the land area of the State and covering part or all of the 31 counties listed in Table 1. The basin is roughly rectangular in shape, about 135 miles long and 50 to 60 miles wide except for the lower 30 miles where it narrows to about 25 miles. The basin extends north beyond Marion, east beyond Galion and Jackson, and west beyond Kenton, London, and Hillsboro (See Figure 7-1, page 7-31).

The northern line of Highland, Ross and Hocking Counties is the northern boundry line of and also designates the area of the Appalachia Region in this basin.

The main tributaries comprising the Scioto River system are shown in Table 2.

Physical Features

The Scioto River Basin exhibits two distinct geological areas, the glaciated and the nonglaciated, with the dividing line essentially trending northeast-southwest through the city of Chillicothe. The nonglaciated area to the south is a hilly region which physiographically belongs to the Appalachian Plateau. The glaciated area to the north, comprising about 80 percent of the basin, belongs to the Till Plains of the Central Lowlands province. The entire area is underlain by essentially flat lying rocks of sedimentary origin which crop out as a series of roughly parallel north-south belts.

The Till Plains have well defined border lands to the east and west which rise some 300 feet above the main stream within a distance of 20 to 25 miles. The divides at the north and west are composed largely of glacial deposits, whereas the eastern and southern borders are formed by the bedrock hills of the Allegheny Plateau. Along both the eastern and western divides, in places

where preglacial valleys extend into the Scioto Basin, rock may be found at depths exceeding 200 feet, but elsewhere along the divides it is found at comparatively shallow depths. Except in restricted localities where rock has been exposed by post glacial erosion, a layer of drift overlies the bedrock to a depth approaching 80 feet. On this till covered plain, the Scioto River and its principal tributaries have developed largely in accordance with and in consequence of the initial slopes of underlying bedrock. The Till Plains exhibit three fairly distinct topographical subdivisions; the Summit Section, the Gorge Section and the Alluvial Section. The Summit Section extending from the western edge of the basin through Kenton and Marion to Bucyrus is a high, flat, poorly drained plateau with elevations ranging generally from 950 to 1,100 feet above mean sea level.

Between Prospect and Columbus, the main stream and its left bank tributaries, of which Mill Creek is the principal tributary, all pass through narrow valleys and the region is often referred to as the Gorge Section. A few miles to the east the Olentangy flows through a narrow valley paralleling the Scioto. Farther to the east Alum and Big Walnut Creeks are deeply entrenched.

The Alluvial Section, excluding stream valleys, lies at 1,000 feet above mean sea level and comprises the region south of Columbus. In places, the flood plain attains widths as great as three and one half miles. Paint Creek, the largest tributary in the watershed, rises in the glacial plains above the city of Washington Court House and flows southeasterly through rolling country and then through a gorge section to emerge and flow the last 30 miles through a broad fertile valley.

There are no natural lakes in the basin. Major artificial reservoirs include three water supply reservoirs north of Columbus having a combined water surface of 4,000 acres, one flood control reservoir, the Delaware, with a surface area of 1,300 acres, and one conservation and recreation lake on Rocky Fork of Paint Creek with a surface area of 2,000 acres. Construction of multiple-purpose reservoirs at sites on Deer Creek, Paint Creek, Big Darby Creek, Salt Creek, Alum Creek and Mill Creek is planned by the Corps of Engineers in the near future.

Climate

The average annual precipitation in the basin varies from approximately 39 inches in the extreme northeastern portion of the basin to approximately 44 inches in the southwestern portion of the basin. June rainfall averages about the same in all areas.

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OHIO RIVER BASIN COMPREHENSIVE SURVEY. VOLUME V. APPENDIX D. WA--ETC(U)
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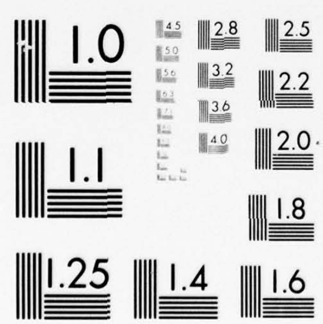


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Average minimum temperatures range from approximately 30°F in January in the northern part of the basin to 36°F in the southern third. Average maximum temperatures range from approximately 74°F in July in the northern part of the basin to 77°F in the southern part of the basin. The frost-free season varies from 166 days in the northern third of the basin to 185 days in the central and southern two-thirds of the basin.

Principal Communities and Industries

Agriculture maintains an important position in the economy of the basin. Stock raising, crop raising and the dairy industry are the principal components of the agriculture industry. The Scioto River Basin is the eastern extremity of the commercial corn belt. Corn, primarily used for feed, is the basis for the basin's agriculture and is located predominantly west of a north-south line through Columbus. Considerable sheep grazing occurs east of this line.

In the nonglaciated area in the southern counties of Ross, Pike and Scioto, due to the hilly terrain and thin soil cover, much of the land is given over to woodland except in the flood plain.

Sand, gravel or limestone is produced in all counties in the basin but the major output is in Franklin County.

There is no significant yield of coal since only the fringe of the coal fields is within the Scioto River Basin in Jackson, Vinton, Hocking and Fairfield Counties. Oil and gas are produced in Morrow County.

Industry of Franklin County, in which Columbus is the major city, produces aircraft and automotive parts, transportation equipment, iron, steel and metal products, food and beverages. Marion and Galion industry produces earth moving equipment. Chillicothe industry produces primarily paper, with shoe manufacture and metal fabrication of secondary importance. Circleville manufacturing consists of plastics, paint, lightbulbs and paper. Jackson County is the center of the Nation's high-silicon iron industry.

Listed in Table 3 are some of the principal cities and their populations from 1910 to 1960.

III WATER RESOURCES

Surface Water Resources

Quantity

Surface flows in the basin above Columbus are afffected by reservoirs constructed on the Scioto River and several tributary streams. Griggs and O'Shaughnessy Reservoirs on the Scioto River, and Hoover Reservoir on Big Walnut Creek are operated by the city of Columbus for water supply. Delaware Reservoir on the Olentangy River was built by the U. S. Army Corps of Engineers primarily for flood control purposes.

In the lower basin, a major reservoir is located on Rocky Fork of Paint Creek near Hillsboro, Ohio. This reservoir was constructed by the State of Ohio and is operated for recreation. Other reservoirs for recreation are Madison Lake near London, Ohio; Hargus Lake near Circleville, Ohio and Lake White near Waverly, Ohio. Hammertown Lake was constructed near Jackson, Ohio for water supply. All of these reservoirs are located on streams tributary to the Scioto River below Columbus. Table 4 shows pertinent data regarding the aforementioned impoundments.

Generally, the streams tributary to the Scioto River and located in the glaciated area below Columbus have higher sustained flows than those streams draining the northern till plains due almost entirely to the presence of extensive deposits of outwash in the valley fill. Other small streams south of the limit of glaciation have very little ground water discharge and low sustained flows. In the State of Ohio, lower sustained flows occur in the Scioto River Basin than in the other major basins which are tributaries to the Ohio River.

Table 5 shows stream data excerpted from the hydrology data prepared by the Corps of Engineers.[1/]

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

Quality

Surface waters in the basin are primarily hard waters of the calcium magnesium bicarbonate or calcium magnesium sulfate type ranging in hardness from 250 to 500 mg/l in the glaciated areas of the basin and from 100 to 300 mg/l in nonglaciated areas. During high flows when a large part of the water is from surface runoff, concentrations of dissolved solids are less than during low flow when the water is largely from underground sources. In addition to natural variations, changes in quality are often the result of domestic and industrial wastes. Mine drainage is not a factor in water quality in the basin and oil field wastes are a factor only in Morrow County.

Ground Water Resources

Quantity

Ground water resources are reported by the U. S. Geological Survey[1/] and the following discussion has been condensed from their report, except as noted.

The northern two-thirds of the basin was covered by a succession of continental ice sheets which, when receeding, left a cover of drift and filled ancestral stream valleys with outwash deposits of unconsolidated sands and gravels.

The water bearing consolidated rocks in the basin consist chiefly of limestones and sandstones. The limestone aquifer underlies the entire basin but dips about 25 feet per mile in a general southeasterly direction. This aquifer is an important source of water in the west-central and northwest portion of the basin. East of a north-south line, approximately through Columbus, the limestones are overlain by shales and are relatively deep. In the central and southern parts of the basin, west of the Scioto River, the limestone formation becomes thinner and shales and dolomite predominate. Sandstones occur in the northeast and east-central parts of the basin.

The major source of large quantities of ground water occurs in the sand and gravel deposits in the valley of the Scioto River between Columbus and its mouth. A potential yield of a 1500 mg/day is a conservative estimate of the ground water available from this area.[2/] This is 50 percent more water than is presently used each day by all towns and cities in Ohio. Between Columbus and Piketon the

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

2/ Ohio Department of Natural Resources Ground Water for Industry in the Scioto River Valley, Buried Valley Investigation, Report No. 1, dated 1965, Page V.

present course of the Scioto River follows the course of a pre-glacial river. Sediments are several miles wide and in many places more than 100 feet deep. Large quantities of water are available in these deposits. Other locations of large quantities of water in unconsolidated deposits are along Walnut Creek, the lower reaches of Big Walnut and Alum Creeks, and the Olentangy River. Large quantities are available in the upper reaches of Big Darby Creek and Deer Creek and the lower reaches of Paint Creek. Wells located in these aquifers generally exceed 100 gallons per minute (gpm) to over 1,000 gpm. Wells in other outwash deposits yield under 100 gpm.

Wells in sandstone have an average yield of 10 to 20 gpm. Wells in the limestone aquifer north of Columbus yield as much as 500 gpm, although most industrial and municipal wells tapping this aquifer in Kenton, Marion and Marysville yield from 250 to 400 gpm.

Quality

Water from unconsolidated glacial deposits is very hard and is high in dissolved solids. Hardness is of the calcium magnesium bicarbonate type with an average hardness of 350 to 400 mg/l and total dissolved solid content of about 550 mg/l.

Water from sandstone aquifers has hardness averaging 200 to 250 mg/l and total dissolved solids of 300 to 350 mg/l.

Water from limestones west of the Scioto River is very hard averaging from 600 to 800 mg/l. Dissolved solids range from around 400 mg/l to over 1,000 mg/l.

IV THE ECONOMY

The Scioto subarea of the Projective Economic Study lies entirely within Ohio. It is roughly coextensive with the drainage basin of the Scioto River. Included in this area are 13 counties which are listed in Tables 6 and 7. For the purpose of utilizing the projections of population and economic activity from the Projective Economic Study to estimate future water requirements and waste loads which can be related to hydrology, the subarea has been divided into two minor areas designated I-1 and I-2. The I-1 area includes seven counties in the southern portion of the basin, and I-2 includes the six northern counties. The counties in each area are listed in Tables 6 and 7 and shown on Figure 7-1, page 7-31.

Economic Profiles

Minor Area I-1

Minor area I-1 is primarily a rural area with a total population of 262,000. The three largest cities are Lancaster, Chillicothe, and Washington Court House. Personal income, which is a composite measure of economic well-being, shows the area to be below average with a per capita income in 1960 of $1,495 as compared to $1,957 for Ohio and $1,850 for the Nation. The counties of Highland, Hocking and Ross are within the area designed as the Appalachian Region.

Manufacturing is the largest employment category, and the manufacturing of the area is characterized by a rather large number of small establishments and a few plants with a large number of employees. The major industries are paper, electrical machinery, food and kindred products, leather goods, and fabricated metals. There are two pulping operations in the area, one of 100 tons per day capacity at Circleville, and one of 300 tons per day capacity at Chillicothe.

The area is centrally located with respect to its principle markets and has good transportation facilities. All industrial categories are expected to increase in output and employment during the next half century.

Agriculture is still important in the area. The fertile soils are used to produce corn which is largely marketed in the form of livestock and livestock products. The value of farm products sold, which was $81 million in 1959, was about equal to the 1954 value. Irrigation is not an important water use in the area with only 300 acres irrigated in 1959.

The mineral industry of the area consists primarily of the production of stone and gravel for construction purposes in all counties except Hocking. Some oil and gas are produced and development drilling is occurring.

Minor Area I-2

Minor area I-2 consisting of the northern part of the Scioto Basin is dominated by the city of Columbus in Franklin County which is designated a Standard Metropolitan Statistical Area. The population of the area in 1960 was 851,200 with 80 percent of it located in Franklin County. Delaware and Marion, with 13,300 and 37,100 populations respectively, are the other larger cities in the area. Ninety-two percent of the Franklin County population was urbanized compared to only 42 percent in the remaining five counties. Per capita income in the area was above average in 1960 being $2,001 compared to $1,957 for Ohio and $1,850 for the Nation. However, when Franklin County is considered separately from the other five counties, the income figures are $2,100 compared to $1,600 for the other counties.

In 1960, manufacturing was the most important employment category with 85,300 workers. This was a 38.5 percent increase over 1950 compared to a 15.1 percent increase for the State. The most important manufacturing categories in 1960 were transportation equipment, machinery (including electrical machinery), fabricated metals, and food processing. Most of the manufacturing is located in Columbus, but some manufacturing activity takes place in Hardin, Marion, and Delaware Counties.

Agriculture declined in importance in this area between 1954 and 1959 with a decline in employment and acres in farms and a decline of about $3 million in farm products sold leaving sales in 1959 equal to $65 million. The farm economy is based on corn and livestock production.

Oil production is important in Morrow County where oil fields are still being developed.

Minor area I-2 has a rather large noncommodity employment category including government and education along with other services because of the location of the State Capital and Ohio State University in Columbus.

Projected Population and Industrial Activity

Population in the Scioto subarea is projected to grow from 1.1 million in 1960 to 1.6 million in 1980 and to 2.6 million by 2020. This increase represents an increase of the subarea's share of the Ohio River Basin population from six to seven percent between 1960 and 1980.

Table 6 shows the 1960 and projected population for the I-1 and I-2 minor areas.

According to the Projective Economic Study, output from manufacturing is expected to increase from $2.6 billion in 1960 to $17.5 billion in 2010, while agricultural output is projected to increase from $231 million to $347 million during the same period.

Table 7 shows 1960 manufacturing output, total employment and manufacturing employment. Projections to 1980, 2000, and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Scioto subarea in the Projective Economic Study, eighteen other counties have land area within the basin. These counties are listed in Table 8. Some of these counties have significant water using communities and significant sources of pollution within the basin and projections of their water needs and organic waste loads are based on the projections of the adjacent Projective Economic Study subarea, if not included in the study area, or based on the projections of the subarea in which they are located.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

There are 59 central water supply systems in the Scioto River Basin, serving a population of 777,160. The average daily water use is 80.923 mgd amounting to 105 gallons per capita daily use.

In the basin, 89 percent of the water used for municipal supplies is from surface sources. Columbus, utilizing surface sources, accounts for approximately 76 percent of the total municipal water use. Most of the smaller communities have ground water sources.

The present municipal and industrial water use in the basin is listed by county and totaled for economic subareas and the basin in Table 9. In the lower basin, designated as minor area I-1, the major communities of Chillicothe, Circleville and Washington Court House account for approximately 56 percent of the population served by central systems and approximately 52 percent of the water use. The other 23 communities account for the remaining water use. The major industrial water use is at Chillicothe and Circleville accounting for 92 percent of the total estimated water use in the minor area. In the upper basin, designated as minor area I-2, the major communities are the Columbus S.M.S.A., Delaware and Marion which account for approximately 93 percent of the population served and over 97 percent of the water use.

In other areas in the basin not included in the A. D. Little Economic Base Study, the largest community is Galion in Crawford County where a population of 12,600 uses over 1 mgd.

Based on population increase and projected industrial activity, estimated water use will increase in the Scioto River Basin as shown in Table 10. It is estimated that total municipal and industrial water requirements will increase more than fourfold by 2020. The major increases will probably occur in or about the present centers of population and industrial activity.

In minor area I-1, water use is projected to increase to over six times the 1960 use. The major increase will probably be located in Chillicothe, Circleville and Washington Court House, with the major industrial needs located in the Chillicothe-Circleville area.

Projected water use in minor area I-2 indicates a 3.5 increase by 2020. The major increase will probably be located in or about the present centers of population in Columbus, Delaware and Marion, with the major need occurring at Columbus.

In other areas, a fourfold increase by 2020 is projected with the major needs occurring at Galion.

Water Supply Problems

The projected total water supply figures shown in Table 10, the 1 day in 30 years low flow data given in Table 5, and availability of ground water reported in the U. S. Geological Survey1/ were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11 are problem areas with the approximate time of onset.

In minor area I-1, the total water use is projected to increase to 89 mgd by 1980, 155 mgd by 2000, and 265 mgd by 2020. Approximately 85 percent of the projected water use in this subarea will be for industrial use. It is assumed that increased industrial activity will occur in the area of present industrial development in the Chillicothe and Circleville area where ample ground water is available. Greenfield is presently encountering water supply problems and municipal water needs as projected will exceed the dependable yields of presently developed sources at Washington Court House, Chillicothe, Hillsboro, and West Jefferson by 1980, Circleville by 2000, and at London by 2020. Indications are that ground water sources at Chillicothe, West Jefferson, London and Circleville can be developed to meet increased needs. Hillsboro and Washington Court House are presently using surface water sources and probably can develop additional storage either by construction of impounding or upland reservoirs. Indications are that ground water sources at Greenfield are unreliable and the city is planning to develop a source of supply in a proposed Federal multipurpose reservoir.

In the I-2 minor area, the major water supply problem will occur in Franklin County. Columbus, the principal municipality, has developed surface water storage having a safe yield of 100 mgd and also a limited ground water development for emergency use. By 1980, it is projected that 148 mgd will be required in the I-2 minor area. In 1960, 87 percent of the municipal water use in

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11

SCIOTO RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Washington Court House	I-1		X		
Greenfield	I-1	X			
Hillsboro	I-1		X		
London	I-1				X
West Jefferson	I-1		X		
Circleville	I-1			X	
Chillicothe	I-1			X	
Columbus	I-2		X		
Hilliard	I-2			X	
Reynoldsburg	I-2			X	
Kenton	I-2			X	
Marion	I-2		X		
Galion	*		X		
Sabina	I-2			X	
Westerville	I-2		X		

* Not included in Projective Economic Study area.

the I-2 minor area was in Franklin County. Assuming in 1980 the same percentage of water use, approximately 102 mgd will be required in Franklin County. Since nearly all of the water at present is used by Columbus, the need for additional supply should be planned prior to 1980. By 2000, the need is projected to approximately 150 mgd and by 2020, 200 mgd. Possible solutions for Columbus water supply needs are: (1) development of extensive well fields to tap aquifers along the Scioto and Olentangy Rivers, (2) storage of surface water in single-purpose reservoirs, or (3) storage in Federal reservoirs constructed for multipurpose use.

Projected municipal water use will exceed the dependable yield of presently developed sources at Marion and Galion by 1980 and at Hilliard, Reynoldsburg, Kenton and Sabina by 2000. At present, Marion uses wells and surface water from the Little Scioto River as the source of supply. Additional sources of supply would probably be developed by impounding streams in the area. Galion uses upground storage of water from the Olentangy River as its source of supply. To meet increased demands, further development of upground storage will probably be required. Hilliard and Reynoldsburg could probably expand their present well fields to meet increased demand, although definitive studies may indicate that connection to the Columbus water system may be the best solution. However, a regional water supply system for the Franklin-Delaware County complex may be desirable. Sabina and Kenton will probably have to develop surface sources to supplement their present well supplies.

Undoubtedly, there are other smaller communities which will have water supply problems, but it is beyond the scope of this report to define these problem areas.

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

Present organic waste loads generated before treatment are shown in Table 12. In the lower Scioto River Basin, defined generally by minor area I-1 boundaries, approximately 85 percent of the present organic waste loads are due to discharges by industry, 90 percent of which is discharged in the Chillicothe-Circleville area. Major sources of municipal organic waste discharges occur at Chillicothe, Circleville and Washington Court House.

In the upper Scioto River Basin, defined generally by minor area I-2, over 60 percent of the estimated organic waste loads are due to municipal discharges, of which 87 percent originates in Franklin County. Major sources of municipal organic waste discharge also occur at Marion, Delaware, and Galion.

Shown in Table 13 are the base and projected waste loads generated before treatment for the minor areas. Waste loads are projected to increase sixfold in minor area I-1, more than 3.5 times in minor area I-2, and about 4.5 times for other areas in the basin not included in economic Subarea I.

Water Quality Control Problems

Listed in Table 14 are the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures beyond secondary treatment for pollution control.

The major water quality control problem in the basin is in the Scioto River below Columbus. Columbus presently operates secondary treatment facilities and obtains reductions in organic constituents in the range of 85-90 percent, before discharging residual organics to the stream. Low flow releases ranging from 5 cfs to 40 cfs dependable flow in the summer season (not including return flows from Columbus) are not capable of assimilating present residual organic waste loads without degradation of the stream. Assuming secondary treatment, total flows in the order of 300 cfs are needed at the present (1960), 475 cfs in 1980, 620 cfs in 2000, and 780 cfs in 2020 including return flows from the city of Columbus. Provision of the above flows at Columbus will maintain satisfactory conditions at Circleville and Chillicothe after secondary treatment

TABLE 14

SCIOTO RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Scioto River-Main Stem	Kenton	I-2	X			
Scioto River-Main Stem	Columbus	I-2	X			
Scioto River-Main Stem	Circleville	I-1		X		
Scioto River-Main Stem	Chillicothe	I-1			X	
Little Scioto River	Marion	I-1	X			
Fulton Creek	Richwood	I-2	X			
Mill Creek	Marysville	I-2	X			
Olentangy River	Galion	*	X			
Whetstone Creek	Mt. Gilead	I-2	X			
Blacklick Creek	Reynoldsburg	I-2	X			
Alum Creek	Westerville	I-2	X			
Little Darby Creek	West Jefferson	I-1	X			
Deer Creek	London	I-1	X			
Paint Creek	Greenfield	I-1	X			
Rocky Fork Creek	Hillsboro	I-1	X			
Paint Creek	Washington Court House	I-1	X			
Little Salt Creek	Jackson	H-3	X			
Wilson Creek	Sabina	L-2	X			
Big Darby Creek	Plain City	I-1	X			

*Not included in Projective Economic Study of Ohio River Basin.

of all wastes. However, storage for purpose of regulation of streamflow for water quality control after secondary treatment of the organic constituents of wastes, appears to be only a partial solution in the main stem below Columbus, as the quantity of water required does not appear to be available. It appears that treatment beyond the normal secondary should be investigated for the Columbus area.

Stream conditions in the Little Scioto River below Marion are unsatisfactory at present with design flow less than 2 cfs. Total summer flows in the order of 40 cfs are required at the present, 75 cfs in 1980, 120 cfs in 2000, and 145 cfs will be required in 2020.

In the Olentangy River below Galion, design flow is about 1 cfs. Total summer flows in the order of 20 cfs are required at the present, increasing to 30 cfs in 1980, 40 cfs in 2000, and 55 cfs in 2020.

Summer flows in the order of 30-40 cfs by 2020 will be needed in the Scioto River stream reaches below Kenton with a design flow of less than 3 cfs, Mill Creek below Marysville with a design flow of 1 cfs, and Paint Creek below Greenfield with a design flow of about 3 cfs. As all of these communities are in headwater areas with very low summer flow in the streams, flow regulation is needed at the present.

Below Washington Court House, Paint Creek has a design flow of less than 3 cfs and summer flows in the order of 20 cfs are needed at the present, increasing to 30 cfs in 1980, 40 cfs in 2000, and 55 cfs in 2020.

Summer flows in the order of 10-30 cfs by 2020 will be needed in Blacklick Creek below Reynoldsburg, Little Darby Creek below West Jefferson, Rocky Fork Creek below Hillsboro, and Deer Creek below London, where design flows are less than 5 cfs.

Summer flows in the order of less than 20 cfs by 2020 will be required in Fulton Creek below Richwood, Wilson Creek below Sabina, Big Darby Creek below Plain City, Alum Creek below Westerville, and Little Salt Creek below Jackson. Summer flows in the order of 30 cfs by 2020 will be required in Whetstone Creek below Mount Gilead. The design flows for all of the streams are less than 5 cfs. There are undoubtedly other small tributaries adversely affected by discharge or residual wastes remaining after secondary treatment, but it is beyond the scope of this report to define all of them.

Regulation of streamflow for the purpose of water quality control, however, does not appear to be a feasible solution for many municipalities located on headwater reaches of tributaries. Communities such as Marion, Galion, Washington Court House, Kenton, Marysville and Greenfield may find that holding ponds used for "polishing" the effluent and for discharge during periods of higher natural flow may be a more practical solution to the pollution problems of these cities.

Quality problems unrelated to population are heat and chloride pollution. Major sources of heat release to streams from thermal power generating plants in the basin are located in Franklin County. Plants with a capacity of 230.8 megawatts, 45.5 megawatts, and 75 megawatts use surface water as a source of cooling water and during periods of low flow are the cause of high stream temperatures in localized stream reaches.

The chloride pollution is the result of oil drilling operations beginning in 1962 in Morrow County in the headwaters of Whetstone Creek, a tributary of the Olentangy River, and Alum Creek, a tributary of Big Walnut Creek. The ground water supply of the village of Cardington has been affected by brine pollution, as has Alum Creek, serving as a source of supply for the city of Westerville. The new regulations of the Division of Oil and Gas, Department of Natural Resources, State of Ohio, require operators to inject all salt water and other oil field wastes into deep disposal wells. This regulation of oil well operations has resulted in the improvement of chloride concentration in the streams.

TABLES

TABLE 1

SCIOTO RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Ohio		Adams	23.0
"		Allen	0.7
"		Auglaize	3.2
"		Champaign	19.2
"		Clark	4.4
"		Clinton	16.6
"		Crawford	22.0
"	*	Delaware	100.0
"	*	Fairfield	39.5
"	*	Fayette	99.9
"	*	Franklin	100.0
"		Greene	4.0
"	*	Hardin	51.0
"	*	Highland	46.4
"	*	Hocking	36.3
"		Jackson	38.5
"		Knox	1.1
"		Licking	6.8
"		Logan	27.4
"	*	Madison	98.8
"	*	Marion	79.6
"	*	Morrow	66.1
"		Perry	1.1
"	*	Pickaway	100.0
"		Pike	90.4
"		Richland	0.6
"	*	Ross	99.8
"		Scioto	40.3
"	*	Union	100.0
"		Vinton	29.2
"		Wyandot	0.3

*Counties considered in economic projections of Scioto River Basin.

TABLE 2

SCIOTO RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from Confluence with Ohio River
Scioto River	6,510	235	0
Little Scioto River	110	30	175
Mill Creek	185	47	155
Olentangy River	536	89	132
Big Walnut Creek	557	75	116
Big Darby Creek	557	82	100
Deer Creek	408	71	85
Paint Creek	1,143	101	63
Salt Creek	553	47	51

TABLE 3

SCIOTO RIVER BASIN

Population of Principal Communities

City	County	1910	1920	1930	1940	1950	1960
Columbus	Franklin	181,511	237,031	290,564	306,087	375,901	471,316
Marion	Marion	18,232	27,891	31,084	30,817	33,817	37,079
Upper Arlington 1/	Franklin	-	620	3,059	5,370	9,024	28,486
Chillicothe	Ross	14,508	15,831	18,340	20,129	20,133	24,957
Whitehall 1/	Franklin	-	-	-	-	4,877	20,818
Bexley 1/	Franklin	682	1,342	7,396	8,705	12,378	14,319
Delaware	Delaware	9,076	8,756	8,675	8,944	11,804	13,282
Galion	Crawford	7,214	7,374	7,674	8,685	9,952	12,650
Washington Court House	Fayette	7,277	7,962	8,426	9,402	10,560	12,388
Circleville	Pickaway	6,744	7,049	7,369	7,982	8,723	11,059
Worthington 1/	Franklin	-	705	-	1,569	2,141	9,239

1/ Part of Columbus, Ohio urbanized area.

TABLE 4

SCIOTO RIVER BASIN

Reservoirs--Area 100 Acres or Greater

Name	Purpose	Perm.Pool Area (acres)	Storage (acre-feet) Flood Control	Water Supply	Other
O'Shaughnessy	W - R (L)	829	-	13,125	-
Griggs	W - R (L)	363	-	3,450	-
Hoover	W - R (L)	2,825	-	60,480	-
Delaware	F - R - A	950 1/	123,600 1/	-	8,400 1/
Rocky Fork	R	2,020	-	-	34,100
Hammertown Lake	W - R (L)	176	-	4,600	-
Madison Lake	R	106	-	-	594
Hargus Lake	R	146	-	-	2,800
Lake White	R	337	-	-	3,735
Big Darby Creek (U.C.)	F - R	676	121,620		7,339 2/
Deer Creek (U.C.)	F - R	727	96,120		6,420 2/
Paint Creek (U.C.)	F - R	711	136,126		8,909 2/

F - Flood Protection

W - Water Supply

R - Recreation ((L) Limited)

A - Low Flow Regulation

1/ Winter Pool and Storage

2/ Minimum Pool

U.C. - Under Construction

TABLE 5

SCIOTO RIVER BASIN

Flow Data[1/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Scioto River						
Prospect	571	449	3.5	10,100	7.9	-
Columbus[4/]	1,624	1,336	42	68,200	3/	19
Chillicothe[4/]	3,847	3,294	160	144,000	184.5	71
Higby[4/]	5,129	4,370	244	177,000	-	-
Olentangy River						
Delaware	387	348	0.1	14,100	1[5/]	-
Big Walnut Creek						
Rees	544	487	5	59,800	7.0	-
Big Darby Creek						
Darbyville	533	438	1.4	49,000	6.2	-
Paint Creek						
Bourneville	808	788	6.7	52,100	7.8	-

1/ Excerpted from Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.
2/ Natural flow.
3/ Value omitted since correlation between return flows from Columbus and natural flow not available.
4/ Flow on Scioto above Columbus regulated by Griggs and O'Shaughnessy Reservoirs since 1924. Diversion from Big Walnut Creek to Scioto River from Hoover Reservoir since 1956.
5/ Prior to construction of Delaware Reservoir. Dependable flow in summer season, ranges from 5 to 40 cfs.

TABLE 6

SCIOTO RIVER BASIN

Economic Subarea I
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation I-1									
Ohio	Fairfield	63,900	29,900						
"	Fayette	24,800	12,400						
"	Highland	29,700	10,900						
"	Hocking	20,200	6,400						
"	Madison	26,500	9,200						
"	Pickaway	35,900	11,100						
"	Ross	61,200	25,000						
	Subtotal	262,200	104,900	452,400		636,000		850,000	
Area Designation I-2									
Ohio	Delaware	36,100	13,300						
"	Franklin	683,000	629,400						
"	Hardin	29,600	12,700						
"	Marion	60,200	37,100						
"	Morrow	19,400	2,800						
"	Union	22,900	5,000						
	Subtotal	851,200	700,300	1,112,600		1,444,600		1,770,000	
Total Subarea I		1,113,400	805,200	1,565,000	1,252,600	2,080,600	1,750,300	2,620,000	2,280,500

TABLE 7

SCIOTO RIVER BASIN

Economic Subarea I
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg. Output*	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation I-1													
Ohio	Fairfield	23,000	9,500										
"	Fayette	8,800	2,100										
"	Highland	10,400	2,400										
"	Hocking	6,200	2,400										
"	Madison	8,600	2,400										
"	Pickaway	10,600	2,700										
"	Ross	19,000	5,800										
	Subtotal	86,600	27,300	647	191	155	256	272	206	523	392	241	1040
Area Designation I-2													
Ohio	Delaware	13,200	3,400										
"	Franklin	256,700	67,200										
"	Hardin	10,200	3,000										
"	Marion	21,300	6,800										
"	Morrow	6,700	2,500										
"	Union	8,300	2,400										
	Subtotal	316,400	85,300	2,015	129	140	231	169	171	444	251	202	845
Total Subarea I		403,000	112,600	2,662	142	144	237	192	179	464	282	212	892

*In millions of 1960 dollars.
**1960 = 100

TABLE 8

SCIOTO RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Ohio	Adams	K-3	Ohio-Cincinnati
"	Allen	X	
"	Auglaize	X	
"	Champaign	L-2	Little Miami-Miami
"	Clark	L-2	Little Miami-Miami
"	Clinton	L-2	Little Miami-Miami
"	Crawford	X	
"	Greene	L-2	Little Miami-Miami
"	Jackson	H-3	Ohio-Huntington
"	Knox	F-2	Muskingum
"	Licking	F-1	Muskingum
"	Logan	L-2	Little Miami-Miami
"	Perry	F-1	Muskingum
"	Pike	H-1	Ohio-Huntington
"	Richland	F-2	Muskingum
"	Scioto	H-1	Ohio-Huntington
"	Vinton	H-3	Ohio-Huntington
"	Wyandot	X	

X - Not included in Projective Economic Study of Ohio River Basin.

TABLE 9

SCIOTO RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation I-1											
Ohio	Fairfield	4	4,750	4,750		.220	.220		46	Wells	1.200
"	Fayette	3	15,135	1,635	13,500	.962	.105	.857	64	Wells and Reservoir	.832
"	Highland	3	12,350	6,350	6,000	1.054	.574	.480	85	Wells and Reservoir	.292
"	Hocking	1	600	600		.050	.050		83	Wells	0
"	Madison	5	13,725	13,725		1.094	1.094		80	Wells	.137
"	Pickaway	4	14,890	3,390	11,500	1.137	0.297	.840	77	Wells and Infiltration Gal.	2.026
"	Ross	6	30,140	30,140		2.000	2.000		67	Wells	31.006
	Subtotal	26	91,590	60,590	31,000	6.517	4.340	2.177	71		35.493
Area Designation I-2											
Ohio	Delaware	4	17,405	400	17,005	1.700	.030	1.670	98	Olentangy R.-Creeks-Res.-Wells	.952
"	Franklin	6	570,620	21,120	549,500	62.700	1.670	61.030	110	Scioto River - Alum & Big Walnut Cr.	14.542
"	Hardin	4	11,005	11,005		1.145	1.145		104	Wells	.374
"	Marion	3	40,800	1,000	39,800	4.380	.040	4.340	107	Little Scioto R. - Olentangy R.	.873
"	Morrow	2	4,515	4,515		.410	.410		91	Wells	.155
"	Union	3	8,250	3,300	4,950	1.120	.340	.780	136	Mill Creek and Wells	.673
	Subtotal	22	652,595	41,340	611,255	71.455	3.635	67.820	110		17.569
Other Areas in Basin											
Ohio	Champaign	2	2,900	2,900		.245	.245		85	Wells	0
"	Clinton	1	2,500	2,500		.156	.156		63	Wells	.069
"	Crawford	1	12,600		12,600	1.020		1.020	81	Scioto R. and 2 Reservoirs	.952
"	Jackson	2	7,500	500	7,000	.910	.030	.880	121	Lake, Buckeye Creek, Wells	1.220
"	Logan	2	1,590	990	600	.150	.090	.060	94	Rush Creek and Reservoir	0
"	Pike	3	5,885	5,885		.470	.470		80	Wells	0
	Subtotal	11	32,975	12,775	20,200	2.951	.991	1.960	89		2.241
	TOTAL	59	777,160	114,705	662,455	80.923	8.966	71.957	104		55.699

TABLE 10

SCIOTO RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation I-1												
From Central Supplies	91,590	71	6.5	176,000	86	15.1	259,000	93	24.1	360,000	98	35.3
Industrial			35.5			73.9			131.0			229.7
Subtotal			42.0			89.0			155.1			265.0
Area Designation I-2												
From Central Supplies	652,595	110	71.5	932,000	124	115.6	1,265,000	133	168.3	1,620,000	139	225.2
Industrial			17.6			32.7			54.1			92.1
Subtotal			89.1			148.3			222.4			317.3
Other Areas in Basin												
From Central Supplies	32,975	91	3.0	47,900	94	4.5	65,000	98	6.4	83,000	101	8.4
Industrial			2.2			4.2			6.9			11.7
Subtotal			5.2			8.7			13.3			20.1
Scioto River Basin												
From Central Supplies Total	777,160	104	81.0	1,155,900	117	135.2	1,589,000	125	198.8	2,063,000	130	268.9
Industrial Total			55.3			110.8			192.0			333.5
GRAND TOTAL			136.3			246.0			390.8			602.4

TABLE 12

SCIOTO RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*: Domestic & Commercial	Estimated Industrial
Area Designation I-1						
Ohio	Fairfield	1	2,115	Little Walnut Creek	2,115	21,000
"	Fayette	1	12,385	Paint Creek	12,385	10,500
"	Highland	3	10,895	Paint Creek-Clear Cr.-Rocky Fork	10,895	8,750
"	Hocking	0	0		0	0
"	Madison	4	12,635	Deer Creek-Little Darby Creek	12,635	5,730
"	Pickaway	2	12,700	Scioto River-Little Walnut Cr.	12,700	155,660
"	Ross	2	24,825	Scioto River-N.Fk.Paint Creek	24,825	273,000
	Subtotal	13	75,555		75,555	474,640
Area Designation I-2						
Ohio	Delaware	3	15,545	Olentangy R.-West Fk.-Big Walnut	15,545	10,870
"	Franklin	10	590,895	Scioto R.-Big Walnut Cr.-Little Walnut Cr.-Alum Cr.	590,895	357,100
"	Hardin	3	9,985	Scioto R.-Cottonwood Ditch	9,985	8,210
"	Marion	2	37,755	Little Scioto R.-Olentangy R.	37,755	21,920
"	Morrow	3	4,960	Whetstone Creek	4,960	6,570
"	Union	2	7,080	Mill Cr.-Fulton Cr.	7,080	13,700
	Subtotal	23	666,220		666,220	418,370
Other Counties in Basin						
Ohio	Champaign	1	1,810	Little Darby Creek	1,810	0
"	Clinton	1	2,315	Wilson Creek	2,315	300
"	Crawford	1	12,650	Olentangy River	12,650	5,300
"	Jackson	1	6,980	Little Salt Creek	6,980	11,130
"	Logan	1	600	Rush Creek	600	0
"	Pike	2	5,070	Scioto River	5,070	0
	Subtotal	7	29,425		29,425	16,730
	TOTAL	43	767,200		767,200	910,095

*NOT to be interpreted as waste load to stream.

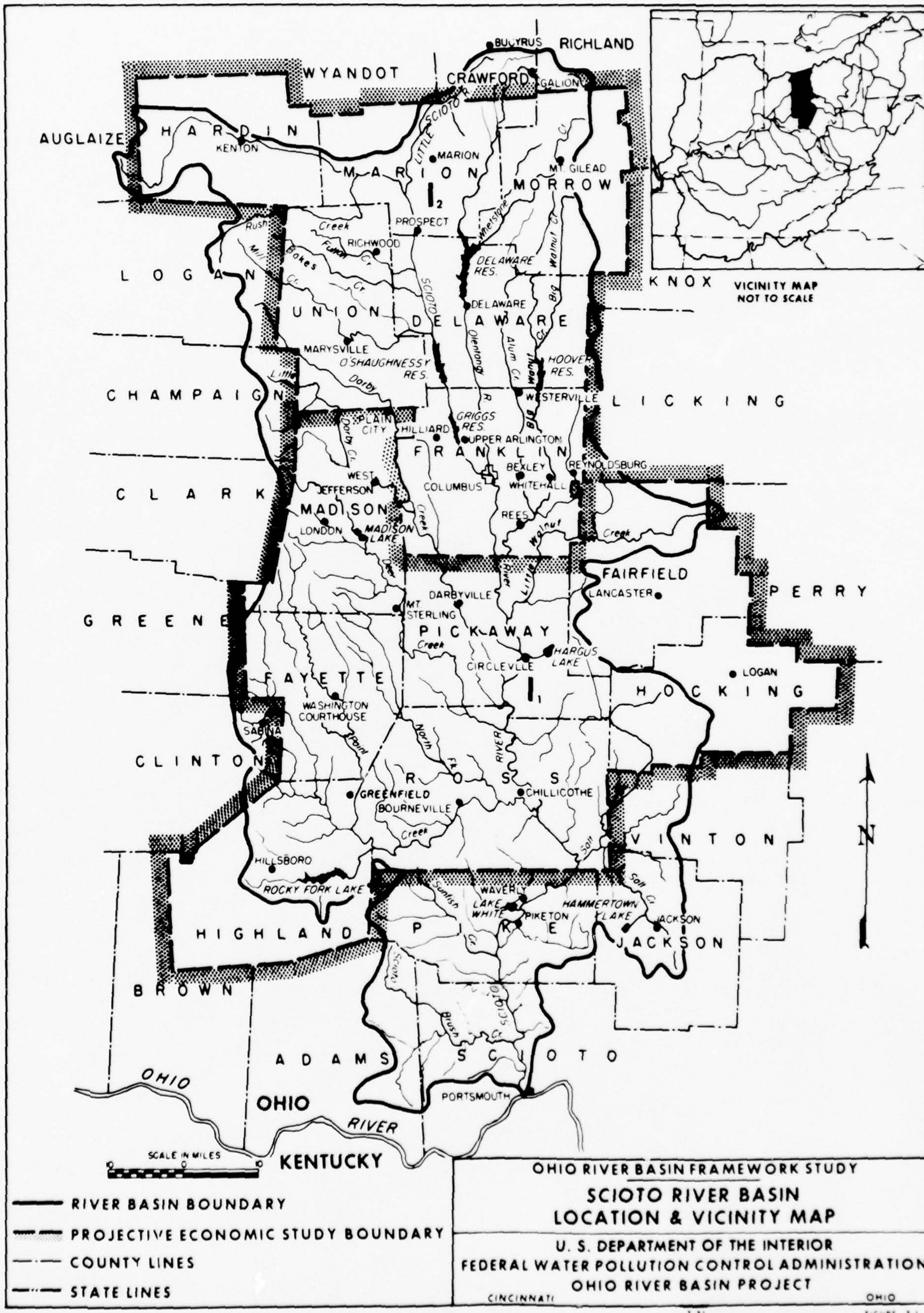
TABLE 13

SCIOTO RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation I-1				
Domestic & Commercial	75,555	145,000	213,000	296,000
Industrial	474,635	978,000	1,727,000	3,030,000
Subtotal	550,190	1,123,000	1,940,000	3,326,000
Area Designation I-2				
Domestic & Commercial	666,220	968,000	1,310,000	1,680,000
Industrial	418,370	776,000	1,288,000	2,185,000
Subtotal	1,084,590	1,744,000	2,598,000	3,865,000
Other Areas in Basin				
Domestic & Commercial	29,425	42,700	58,000	74,200
Industrial	16,730	31,000	51,500	87,500
Subtotal	46,155	73,700	109,500	161,700
Scioto River Basin				
Domestic & Commercial Total	771,200	1,155,700	1,581,000	2,050,200
Industrial Total	909,735	1,785,000	3,066,500	5,302,500
GRAND TOTAL	1,680,935	2,940,700	4,647,500	7,352,700

*NOT to be interpreted as waste loads to the stream.



OHIO RIVER BASIN FRAMEWORK STUDY

SCIOTO RIVER BASIN
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 7.1

LITTLE MIAMI-GREAT MIAMI RIVER BASINS

Subbasin Area
No. 8

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Municipal and Industrial Water Supply Problems

Largest water use in the basin occurs at Xenia, Ohio, in the upper basin, and in communities adjacent to Cincinnati, Ohio, in Hamilton and Clermont Counties, in the lower basin. Ground water sources are used to serve these communities and indications are that by extension of the present well fields projected needs can be met.

Many of the communities in the middle portion of the basin have marginal ground water or surface water sources. Failure to develop dependable sources of water could be a deterrent to future growth. However, it may be feasible to develop adequate water supplies in Federal Reservoirs for these areas.

Water Quality Control Problems

The more critical stream reaches adversely affected by residual organic waste discharges from secondary treatment plants, are Little Beaver Creek below the Montgomery County-Beaver Creek Sanitary District outfall, Shawnee Creek below Xenia and the East Fork of the Great Miami River below Batavia. In addition, many of the smaller tributaries have unsatisfactory conditions during the low flow periods due to residual organic waste discharges from communities.

Great Miami River Basin

Municipal and Industrial Water Supply Problems

Ground water is used almost exclusively as a source of supply by municipalities in this basin. The major municipal and industrial water use in the basin occurs in Ohio in the Hamilton-Middletown-Dayton reach of the Great Miami River.

Ground water aquifers appear to have sufficient storage capabilities to meet future needs, if the recharge from the Great Miami River to the glacial outwash aquifers is maintained or artificially improved. The low flow (90 pct duration flow) of the Great Miami River at Hamilton is almost 500 cfs, so water in adequate quantities will probably always be available for recharging of the aquifers.

Dayton, Ohio, is in an area where there are vast quantities of untapped ground water. Alternative surface water sources potentially could provide storage to meet water-supply needs for the Dayton area after 1980. The proposed Caesar Creek Reservoir in the Little Miami Basin is one possibility. An economic appraisal of relative costs of ground, surface, and conjunctive water supplies for Dayton, as well as the costs for other benefits that can be derived from reservoirs -- such as flood control, recreation, navigation, etc. should precede planning for any individual facility.

Water Quality Control Problems

The major problem area in the Great Miami River Basin is in the Great Miami River below Dayton, Ohio. Even with secondary treatment of organic wastes by the city of Dayton, present critical low summer flows in the Great Miami River are not sufficient to assimilate residual organics discharged to the stream without degradation of water quality. This condition will become worse under projected growth and industrial activity.

Major industrial activity resulting in the discharge of organic wastes occurs in the Hamilton-Middletown-Dayton reach. Assuming removals equivalent to secondary treatment of these wastes as well as municipal wastes in this reach, provision of stated flows at Dayton will maintain satisfactory conditions at downstream points.

Stream conditions are unsatisfactory at the present due to residual organic discharges in the main stem of the Great Miami River below Sidney and Piqua, in the Stillwater River below Covington, in Greenville Creek below Greenville, in Sevenmile Creek below Eaton, in Fourmile Creek below Oxford, in Buckongahelas Creek below Bellefontaine and during periods of low flow in the East Fork of the Whitewater River below Richmond, Indiana. Projected population growth and industrial activity indicates that by 1980 unsatisfactory stream conditions will occur in the main stem Great Miami River below Troy and Vandalia, in the Mad River below Springfield and in the Stillwater River below West Milton. By 2000, unsatisfactory stream conditions will occur below Tipp City on the main stem Great Miami River, below Urbana in the Mad River and below Connersville, Indiana on the West Fork of the Whitewater River. In addition, many of the smaller tributaries have unsatisfactory conditions due to residual organic waste discharges from communities.

II DESCRIPTION OF STUDY AREA

The Little Miami River and the Great Miami River along with Mill Creek, a minor tributary of the Ohio River, drain the southwestern portion of the State of Ohio and a portion of the southeastern corner of the State of Indiana. Mill Creek is considered as a main stem tributary and will be discussed as part of the Cincinnati main stem drainage. The Great Miami River Basin and the Little Miami River Basin are grouped in the Projective Economic Study and have similar physical features and geologic history, as well as a similar economic base.

Little Miami River Basin

Location and Boundaries

The Little Miami drainage area is located entirely in the southwestern portion of the State of Ohio. The Little Miami River rises in Clark County Ohio and flows in a general southwesterly direction for approximately 106 river miles to its confluence with the Ohio River in the eastern suburbs of the city of Cincinnati, 464 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is 1,755 square miles, covering all or part of the 12 counties listed in Table 1a, but lies principally within the counties of Clermont, Clinton, Greene and Warren (See Figure 8-1).

The main tributaries comprising the Little Miami River system are shown in Table 2a.

Physical Features

The entire Little Miami River Basin lies in the Glaciated Till Plains division of the Central Lowlands physiographic province. The topography is typified by level to gently rolling plains in the upper and middle portion of the basin which are broken by the wide valleys of the major streams. In the lower reaches, the topography changes to rolling and hilly terrain.

Glaciation by at least two major ice sheets has affected the watershed. The Wisconsin sheet going down to about the northern

boundary of Hamilton County and the Illinois sheet covering the entire area. Upon receeding, the outwash carried by meltwaters filled the major drainageways. The glacial outwash material consists primarily of coarse sand and gravel. Most of the upland areas were covered with till composed of clay, sand and stones.

The entire area is underlain by consolidated rocks of sedimentary origin, including shale, limestone and dolomite, ranging in age from Late Ordovician to Silurian.

There are no large natural lakes in the basin. Principal bodies of water are Cowan Lake on Cowan Creek south of Wilmington, Ohio and Stonelick Lake on Stonelick Creek near Edenton, Ohio. The Corps of Engineers is studying multiple purpose reservoirs on Caesar Creek near Harveysburg and on the East Fork Little Miami River near Batavia, Ohio.

Climate

The average annual precipitation over the Little Miami River Basin is about 41 inches, varying from over 38 inches in the northern part of the basin, to about 46 inches around Wilmington, Ohio in the central part of the basin, and 40 inches in the southern part of the basin, generally well distributed throughout the year.

The mean average annual temperature for the Little Miami River Basin is about 54°F. Average minimum temperature is about 32°F in January with the average maximum temperature of about 77°F occurring in July. Frost-free days vary from about 165 days in the northern portion to about 190 days in the southern portion.

Principal Communities and Industries

The major city in the basin is Xenia. Other principal communities are shown in Table 3a.

Cattle, hog and poultry raising and the dairy industry are the principal components of the agriculture industry in the basin. Corn, primarily used for feed, and wheat are the principal crops.

Sand and gravel, primarily for the construction industry, is produced in all counties, but the major output is in Hamilton County. Clay, used in the manufacture of cement, limestone for road metal, and aggregate for concrete are processed primarily in Greene County.

Industry in the basin at Xenia, includes food processing, furniture and machinery manufacturing; at Wilmington, machine tools and castings; and at Lebanon, heating equipment, manufacturing and structural steel fabrication.

Great Miami River Basin

Location and Boundaries

The Great Miami River drainage area is located in the southwestern portion of the State of Ohio and the southeastern portion of the State of Indiana. The portion of the drainage area in the State of Ohio lies principally within the counties of Butler, Preble, Montgomery, Darke, Miami, Clark, Champaign, Shelby and Logan and in the State of Indiana, principally within the counties of Wayne, Fayette, Union and Franklin.

The Great Miami River rises in Logan County, Ohio, and flows in a southwesterly direction for approximately 172 river miles to its confluence with the Ohio River near the Ohio-Indiana State boundary line, 491 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin, covering all or part of the 25 counties listed in Table 1b, is 5,385 square miles, of which 3,950 square miles are in Ohio and 1,435 square miles are in Indiana. The Whitewater River enters the Great Miami River at a point five miles above its confluence with the Ohio River and drains all or part of ten counties in Indiana, while the Great Miami River main stem and other tributaries drain all or part of 15 counties in Ohio. These counties are listed in Table 1b.

The main tributaries comprising the Great Miami River system are shown in Table 2b and Figure 8-1.

Physical Features

The entire Great Miami River Basin lies in the Glaciated Till Plains division of the Central Lowlands physiographic province. The topography is typified by level to gently rolling plains in the upper and middle reaches of the basin which are broken by the wide valleys of the major streams. In the lower reaches, the topography changes to rolling to hilly terrain as the rivers and their tributaries flow toward the Ohio River.

Glaciation by at least two major ice sheets has affected the watershed. The Wisconsin sheet going down to about the northern

boundary of Hamilton County and the Illinois sheet covering the entire area. Upon receding, the preglacial valleys were filled with thick deposits of glacial outwash material consisting primarily of coarse sand and gravel. Most of the upland areas are covered with till composed of clay, sand and stones.

The entire area is underlain by consolidated rocks of sedimentary origin, including shale, limestone and dolomite, ranging in age from Late Ordovician to Silurian.

There are no large natural lakes in the basin. In Ohio, Acton Lake near Oxford, Clark Lake near Springfield and Kiser Lake near Urbana, were constructed by the State of Ohio for recreation purposes. In the headwaters region of the Great Miami River Basin, Indian Lake on the main stem and Loramie Lake on Loramie Creek were constructed as feeder lakes for the now abandoned Miami-Erie Canal and are now operated for recreation by the State of Ohio. The Corps of Engineers is constructing two multiple-purpose reservoirs, one, Buck Creek Reservoir at Springfield, Ohio on Buck Creek, a tributary of the Mad River and two, the Brookville Reservoir near Brookville, Indiana on the East Fork of the Whitewater River. Flood flows in the Great Miami River Basin have been regulated since 1920 by five retarding reservoirs. Four of the retarding reservoirs are located on tributaries and one is located on the main stem.

Climate

The average precipitation varies from about 39 inches in the south, to 33 inches in the north, generally well distributed throughout the year.

In the Great Miami River Basin, average annual temperatures vary from 55°F in the southern portion of the basin to 51°F in the northern portion. Mean temperatures range from 33°F in January to 77°F in July in the southern portion of the basin and from 29°F in January to 74°F in July in the northern portion.

Frost-free days in the Great Miami River Basin vary from about 165 days in the northern portion to about 190 days in the southern portion of the basin.

Principal Communities and Industries

Major communities in the basin are Dayton, Springfield, Hamilton, Middletown, Fairborn and Piqua, Ohio, and Richmond and Connersville, Indiana. Other principal communities are shown in Table 3b.

The leading industries in the basin are those concerned with paper and metal. The majority of the pulp and paper mills are located on the Great Miami River between Tipp City and Hamilton, Ohio. Metal plants, producing a wide variety of products ranging from structural steel to intricate machinery, are located in the larger communities in the basin. Industries related to agriculture, such as the dairy, meat packing and canning industries, are prevalent in the basin and constitute a large portion of the industry in the smaller communities. There are also other various types of industries such as textile, rubber, oil refinery, chemical and tobacco.

III WATER RESOURCES

Little Miami River Basin

Surface Water Resources

Quantity

Major recreation reservoirs in the basin are Cowan Lake south of Wilmington, Ohio, and Stonelick Lake near Edenton, Ohio. Neither reservoir has any pronounced effect on surface flows. Both impoundments were constructed by the State of Ohio. Table 4 shows pertinent data regarding these reservoirs.

The streams in the upper basin above Waynesville have good sustained dry weather flows. From Waynesville, southward streams have lower sustained flows but streams with drainage areas in excess of 50 square miles go dry only occasionally.

Streamflow data shown in Table 5a were excerpted from data prepared by the Corps of Engineers.1/

Quality

Surface waters in the natural state in the basin are hard waters containing bicarbonates of calcium and magnesium ranging from about 250 to 400 mg/l in the northern portion of the basin and from about 200 to 300 mg/l in the southern portion. Concentrations of dissolved solids are less during high flows than during low flows when the water is largely from underground sources. Changes in quality are affected in local reaches of the stream by discharges of domestic wastes.

Ground Water Resources

Quantity

Ground water resources are described by the U. S. Geological Survey2/ and most of the following discussion has been condensed therefrom.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The upper part of the basin is underlain by fairly extensive outwash deposits from the continental ice sheets. Outwash sands and gravel are present in the lower Little Miami River Basin only in the reach between Loveland and the mouth. Yields of individual large diameter wells in these deposits are commonly 500 to 1,000 gpm. Most of the other areas are covered with relatively impermeable till and except where sand and gravel deposits within the drift are sufficiently thick and extensive and can be recharged by streams and rainfall the yield to wells is small and uncertain. Their distribution is rather unpredictable.

Bedrock underlying the basin consists essentially of alternating thin beds of calcareous shale and limestone and is generally a poor source of underground water although in the northeastern section of the basin the limestone may yield adequate supplies for farm and domestic needs.

Quality

Water from wells located in glacial outwash material are hard waters of the calcium bicarbonate type and usually contain objectionable amounts of iron and manganese. Hardness ranges from 300 to 400 mg/l with 1.0 mg/l or more of iron.

Great Miami River Basin

Surface Water Resources

Quantity

Major reservoirs in the basin are Indian Lake in the headwaters of the Great Miami River, Loramie Lake located on Loramie Creek, Acton Lake on Four Mile Creek, Clark Lake on Sinking Creek and Kiser Lake on Mosquito Creek. These reservoirs have no direct effect on flow conditions in the Great Miami Basin. Pertinent data relating to these reservoirs are shown in Table 4.

Indian Lake and Loramie Lake along with Grand Lake in the Wabash River Basin were constructed to serve as feeder lakes for the Miami-Erie Canal which by 1845 connected Cincinnati and Dayton with Lake Erie at Toledo. From Cincinnati the canal followed Mill Creek through Hamilton County to Butler County and then followed the Great Miami River through Middletown, Dayton and Piqua. The canal route then followed

Loramie Creek and crossed the divide into the Maumee River Basin. Small portions of this canal remain intact in the Great Miami River Basin and serve as a source of hydropower at Hamilton, Ohio, and a source of water for industry in several communities.

Acton, Clark and Kiser Lakes were constructed by the State of Ohio and are operated for recreation purposes.

Flood flows in the Great Miami River from Dayton to the mouth have been regulated since 1920 by one of the most elaborate flood control reservoir systems in the country. Reservoirs located in the basin were constructed with local funds by a local authority, the Miami Conservancy District. The reservoir dams by nature of their design, which does not involve any movable parts, are nonoperating during periods of normal flow.

The Mad River has high sustained low flow and has the highest unit yield (0.31 cfs/square mile) of all the streams in the State of Ohio. The Stillwater River has below average unit yields for the basin while the Great Miami River above Dayton has a somewhat higher unit yield. The Whitewater River has unit yields typical for a stream underlain by permeable gravel deposits (0.12 cfs/square mile, 90 percent or more of the time).

Shown in Table 5b are streamflow data excerpted from hydrology data prepared by the Corps of Engineers.1/

Quality

Surface waters of the Great Miami River Basin contain moderate amounts of dissolved solids with an average concentration of 400 mg/l and are primarily hard waters of the calcium bicarbonate or magnesium carbonate type averaging about 300 mg/l.

The primary cause of adverse water quality in the Great Miami River Basin is organic wastes from municipal sewerage systems and industrial outfalls. The discharge of heat loads during periods of low flow are of significance in the lower reach of the main stem at Miamisburg and Dayton, Ohio.

Ground Water Resources

Quantity

Glacial outwash deposits underlie nearly the entire course of the Great Miami River south of Dayton and nearly all the course of the

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

Mad River and other major tributary valleys including the Whitewater River. These outwash deposits serve as a source of municipal water supplies for practically all the communities in the basin. While large quantities of water are withdrawn, vast areas of the valley fill remain untapped. Some of the outwash deposits are covered by surface structures built in normal city and industrial development in the larger cities of the basin, but the aquifer nevertheless lends itself to recharge from infiltration from precipitation, as well as induced recharge from streams. Wells developed in this material situated sufficiently near a stream to be recharged by induced infiltration, can yield as much as 3,000 gpm. Wells not receiving induced recharge can be expected to yield 500 to 1,000 gpm.

Bedrock aquifers have never been extensively developed due probably to the abundance of water available in the outwash deposits. Limestones and dolomites occur in the northern part of the area and on the eastern and western edges. Generally, small to moderate ground water supplies of from 10 to 50 gpm can be developed.

Quality

Waters from ground sources average about 450 mg/l of dissolved solids. The water is of the calcium bicarbonate or magnesium carbonate type averaging about 350 mg/l in hardness. Iron content is generally excessive, less than 1.5 mg/l, in water obtained from shallow wells up to 130 feet deep located in outwash deposits and is still higher in the deeper wells located in this material and in limestone shales underlying the basin.

IV THE ECONOMY

Approximately one-fourth of the Little Miami-Great Miami subarea of the Projective Economic Study lies in Indiana and contains the middle and upper reaches of the Whitewater River watershed. The remaining three-fourths of the subarea lies in Ohio, and contains the middle and upper reaches of the Great Miami and Little Miami River drainage basins. For the purpose of utilizing the projections of the subarea for estimating future water requirements and waste loads, which are related to hydrology, the subarea has been divided into two minor areas designated L-1 and L-2. The L-1 minor area includes the four counties of the subarea lying in Indiana on the Whitewater River, and the L-2 minor area includes the remaining 12 Ohio counties. The counties in each minor area are listed in Table 6 and 7.

Economic Profiles

Minor Area L-1

The L-1 minor area had a population of 122,000 in 1960 with Connersville and Richmond the largest cities. The personal per capita income of $1,631 in the minor area was below that for States of Indiana and Ohio, which were $1,832 and $1,957 respectively.

Manufacturing is the most important employment category with Franklin and Wayne Counties experiencing an increase in establishments employing 100 or more employees, from 36 in 1958 to 45 by 1964. The major industries are machinery, electrical machinery, other durables, fabricated metals and primary metals.

Although agriculture had experienced a decline in employment of 4.3 percent per year between 1950 and 1960, the value of farm products sold was $33 million in 1959 representing an increase of $500,000 over 1954. Livestock and livestock products accounted for over 70 percent of the above total value. Irrigation in the area is unimportant, having only 100 acres under irrigation in 1959.

No mining activity was reported in 1960.

Minor Area L-2

Five of the 12 counties in L-2, Butler, Clark, Greene, Miami and Montgomery, are designated standard metropolitan statistical

areas. The major portion of the land area of Greene County is in the Little Miami River Basin. Seventy-nine percent of total L-2 population of 1,297,000 resided in the above five counties in 1960, and their urban population amounted to 80.5 percent of their total population contrasted to only 31.4 percent for the remaining seven counties. Per capita personal income equaled $2,033 there compared to $1,563 in the remaining seven counties and $1,957 in the State.

Although manufacturing employment increased 19.5 percent over 1950 compared to a 15.1 percent increase for Ohio, the area experienced no increase in manufacturing establishments with 100 or more employees between 1958 and 1964, an increase in smaller plants having absorbed the increase in employment. The most important manufacturing industries are machinery, electrical machinery and other nondurables, including paper products, motor vehicles, and printing and allied products.

A pulp mill of 95 tons per day capacity is located at Franklin in Warren County.

Agricultural employment declined 4.3 percent per year between 1950 and 1960 and 134,000 acres were taken out of production between 1954 and 1959. Even so, the value of farm products sold has remained at about the 1959 level of $154 million. Livestock and livestock products accounted for 60 percent of this total and field crops for 34 percent. About 2,000 acres were irrigated in 1959, an increase since 1954 when 1,300 acres were irrigated.

Mining activity is almost exclusively confined to crushed and broken stone and to sand and gravel extraction.

Projected Population and Industrial Activity

Population of the Little Miami-Great Miami subarea is projected to increase from 1.4 million in 1960 to 1.8 million by 1980 and 3.0 million by 2020 (See Table 6). Whereas the subarea contained 7.5 percent of total Ohio River Basin population in 1960, it is expected to contain 8.3 percent by 2000. Table 6 shows the historical and projected population for the L-1 and L-2 minor areas.

Manufacturing output is expected to double by 1980 from $4.5 billion in 1960 to $9.0 billion in 1980 and to be $15.6 billion by 2000. Table 7 shows 1960 total employment, manufacturing employment and manufacturing output. Projections to 1980, 2000, and 2020 for the minor areas are shown as indices using 1960 as the base.

Agricultural output is projected to increase from $301 million in 1960 to $319 million by 1980 and to $406 million by 2000.

In addition to the counties included in the Little Miami-Great Miami subarea in the Projective Economic Study, six other counties have land area within the Little Miami River Basin and ten other counties have land area within the Great Miami River Basin. These counties are listed in Tables 8a and 8b respectively. In some of the counties there are communities with significant water use and projections of their water requirements are based on the projections of the Projective Economic Study subarea in which they have been located.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Little Miami River Basin

Present and Projected Water Use

There are twenty-eight central water supply systems in the Little Miami River Basin, a part of the L-2 minor area, serving a population of 125,730. The 1960 average daily water use is 11.757 mgd, amounting to 94 gallons per capita daily use. Approximately 85 percent of the water used for municipal supplies is from ground sources. The major water users in the upper basin are Xenia in Greene County serving a population of 22,500 with 2.750 mgd from wells, and Wilmington in Clinton County serving a population of 10,000 with 0.913 mgd from a surface source on Cowan Creek. In the lower basin, the water supply systems shown in Hamilton and Clermont Counties serve a population of approximately 55,000 in communities adjacent to the city of Cincinnati. About 90 percent of the population is served from ground sources. The present municipal and industrial water use, by county, is totaled by economic subarea and the basin, and is shown in Table 9a.

Based on population increase and projected industrial activity, estimated water use will increase in the Little Miami River Basin as shown in Table 10a. It is estimated that total municipal and industrial water requirements will triple by 2020. The major increases will probably occur in about the present centers of population and industry.

In the upper basin, the major growth will probably occur in Greene County in the vicinity of Xenia, part of the Dayton S.M.S.A., and in Clinton County around Wilmington.

In the other areas, major population growth will probably occur in Clermont and Hamilton Counties by expansion and extension of the present Cincinnati, Ohio suburbs.

Water Supply Problems

The projected total water supply figures shown in Table 10a, the 1 day in 30 years low flow data given in Table 5a, and availability

of ground water reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to need for future development of sources of water supply.

In the part of minor area L-2, occupied by the Little Miami River Basin, the total water use is projected to increase to 12.7 mgd by 1980, 17.9 mgd by 2000 and to 23.2 mgd by 2020 (Table 10a). Most of the increase will probably be in municipal use.

Listed in Table 11a are the larger communities in the basin which are considered problem areas with the approximate time of onset of the problem.

TABLE 11a

LITTLE MIAMI RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Xenia	L-2		X		
Blanchester	L-2			X	
Yellow Springs	L-2		X		
Deerfield-Hamilton S.D.	L-2		X		
Lebanon	L-2		X		
Mason	L-2		X		
Batavia S.D.-- Pierce-Union	K-2		X		
Loveland	L-2	X			
Milford	K-2		X		
Stonelick S.D.- Miami-Goshen	K-2		X		
Indian Hill	K-2	X			
Wilmington	L-2	X			

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The projections shown should be considered minimal since they are based on the present availability of water from a limited areal source. All of the communities listed as problem areas except Blanchester and Wilmington, use ground water sources. In the lower basin, Indian Hill, Milford, Stonelick Sanitary District and Loveland and Xenia in the upper basin can meet increased needs by expansion and extension of their present well fields. The Batavia Sanitary District serving customers in Clermont County has its source of supply in the aluvium along the Ohio River and should be able to meet future needs by expansion of well field facilities. In the upper basin, glacial outwash along the Little Miami River has considerable potential for further development. However, construction of a reservoir to store water for projected municipal and industrial use, and construction of a distribution system to serve many of the smaller communities in nearby water-short areas could stimulate the economy. Such a reservoir on Caesar Creek, now under study by the Corps of Engineers, could provide this storage. The feasibility of developing either underground or surface sources of supply, or both conjunctively, needs to be objectively studied.

Great Miami River Basin

Present and Projected Water Use

There are 86 central water supply systems in the Great Miami River Basin, serving a population of 935,500. The 1960 average daily water use is 130.609 mgd, amounting to 140 gallons average per capita daily use.

In the basin, approximately 97 percent of the water used for municipal supplies is from ground sources. Approximately 61 percent of the municipal use is developed in Butler and Montgomery Counties, Ohio of which Hamilton and Middletown are the principal cities in the former county and Dayton is the principal city in the latter county. In Ohio, surface water is used as a source of municipal water supply for only three municipalities, College Corner (population served, 1,200) in Butler County, Greenville (population served, 10,500) in Darke County and Piqua (population served, 19,980) in Miami County. Richmond, Indiana has a combined surface and ground source. The Indiana towns of West College Corner and Oldenburg purchase treated surface water from College Corner, Ohio and Batesville, Indiana, respectively.

The present municipal and industrial water use in the basin is listed by county and totaled for economic subareas and the basin in Table 9b. Minor area L-1 consists of four Indiana counties drained primarily by the Whitewater River. The major communities of Connersville and Richmond account for approximately 70 percent of the population served and 88 percent of the water use in the subbasin. The majority of the self-supplied industrial water use is located near these communities.

In the Great Miami River Basin portion of the L-2 minor area, the municipal water use developed in the Hamilton-Middletown-Dayton reach by 11 communities accounts for 69 percent of the total water use in the L-2 area and Springfield accounts for over 12 percent. The other 57 communities account for the remaining water use. About 85 percent of industrial water use in the basin is located in the Hamilton-Middletown-Dayton reach of the Great Miami River, of which about 93 percent is from ground sources. Approximately 61 percent is used for cooling purposes.

In other areas of the basin, the major water use is located in Hamilton County in the lower portion of the basin. Of the 50 mgd developed, approximately 58 percent of the water use is from surface sources and is used primarily for industrial cooling purposes. Approximately 13 mgd of the 20.5 mgd from ground sources is diverted to the Mill Creek drainage basin and serves industries in this area.

Based on population increase and projected industrial activity, estimated water use will increase three fold in the Great Miami River Basin. This is shown in Table 10b. The major increase will probably occur in or about the present centers of population and industrial activity.

In minor area L-1, water use is projected to increase by 2020 to over 4.5 times the 1960 use. The major increases will probably occur in the Richmond and Connersville areas.

Projected water use in the Great Miami River Basin portion of the L-2 minor area is projected to increase approximately 3 fold by 2020 and will probably be located for the most part along the main stem of the Great Miami River from Hamilton to Dayton and beyond, and in the Springfield area on the Mad River.

In other areas, an increase of 3.5 times is projected by 2020 with a proportionate share diverted to the Mill Creek drainage area and the remainder located along the main stem of the Great Miami River.

Water Supply Problems

The projected total water supply figures shown in Table 10b, the 1 day in 30 years low flow data given in Table 5b and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to the need for future development of sources of water supply. Shown in Table 11b are problem areas with the approximate time of onset.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11b

GREAT MIAMI RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Brookville 1/	L-1		X		
Connersville 1/	L-1		X		
Cambridge City 1/	L-1		X		
Centerville 1/	L-1		X		
Richmond 1/	L-1		X		
Fairfield	L-2		X		
Middletown	L-2		X		
New Miami	L-2			X	
Oxford	L-2			X	
Urbana	L-2			X	
Springfield	L-2			X	
Greenville	L-2		X		
Fairborn	L-2		X		
Bellefontaine	L-2		X		
Covington	L-2			X	
Tipp City	L-2			X	
Troy	L-2			X	
West Milton	L-2		X		
Dayton	L-2		X		
Englewood	L-2		X		
Germantown	L-2		X		
Montgomery Co.,Greater Moraine S.D.	L-2			X	
Eaton	L-2		X		
Sidney	L-2			X	
Franklin	L-2			X	

1/ State of Indiana. Where not noted, cities are in the State of Ohio.

In minor area L-1, the total water use is projected to increase to 34.6 mgd by 1980, 56.1 mgd by 2000 and 96.6 mgd by 2020. Approximately 80 percent of the projected water use in this subarea will be supplied by central water supply systems. Municipal water needs as projected will exceed the dependable yields of presently developed sources at Brookville, Connersville, Cambridge City, Centerville and Richmond, Indiana by 1980. Ground water sources can probably be developed at Centerville, Connersville and Cambridge City to meet projected needs. Inventory data indicate that nearly two-thirds of Richmond's source is from impounded surface sources, with the remainder from ground sources. Several alternative solutions to meeting projected needs in the Richmond area are upground storage reservoirs to be filled during periods of medium to high surface flows and expansion and extension of the present well fields. The Brookville Reservoir, that is now under construction by the Corps of Engineers will have a capacity of 89,300 acre-feet for water supply.

In the main stem Great Miami River drainage area, all communities excepting Greenville are using underground sources. The solution to the water supply problems of the communities using ground water are expansion of well fields and recharge of aquifers during periods of medium to high flows since storage capacity in the aquifers appear to be ample to meet projected municipal and industrial water supply needs to 2020. There are large quantities of untapped ground water in the vicinity of Dayton, the area generally is so heavily built up that obtaining new well field areas would be difficult. Dayton may have to consider a supplementary surface water supply after 1980. Alternative surface water sources potentially could provide storage to meet water-supply needs for the Dayton area after 1980. The proposed Caesar Creek Reservoir in the Little Miami Basin is one possibility. An economic appraisal of relative costs of fround, surface, and conjunctive water supplies for Dayton, as well as the costs for other benefits that can be derived from reservoirs -- such as flood control, recreation, navigation, etc. should precede planning for any individual facility. Greenville presently utilizes as a surface source, Greenville Creek, which is fed from morainal deposits and has a high dry weather flow index. It appears that by 1980, based on projected water needs, Greenville's average daily use will be approaching the safe dependable yield. Since ground water is not locally available in large quantities, upground reservoirs may be the solution to the problem.

VI WATER QUALITY CONTROL

Little Miami River Basin

Present and Projected Waste Loads

Present waste loads generated are shown in Table 12a. In the portion of minor area L-2 occupied by the Little Miami River Basin, nearly 90 percent of the present organic waste loads are discharged from municipal sources. Major sources of waste discharges are from Xenia, Montgomery County-Beaver Creek Sanitary District, Wilmington and Lebanon.

In the lower Little Miami River Basin listed as other areas, the larger discharges are at Loveland, Milford and Hamilton County-Sycamore Sewer District. In the East Fork drainage area, the larger organic discharge occurs between Batavia and Milford. As the Cincinnati urban area continues to expand to the east, much of the population increase will be in this drainage area.

Shown in Table 13a are the base and projected waste loads generated for the portion of L-2 occupied by the Little Miami River and for other areas in the basin. Waste loads generated are projected to increase two and one-half times in the basin by 2020.

Water Quality Control Problems

Listed in Table 14a are the more critical areas and the approximate beginning date of the need for stream regulation for quality control after secondary treatment or where further appropriate measures for pollution control must be taken.

Major quality control problems in the basin are in Little Beaver Creek below the secondary treatment plant of the Montgomery County, Beaver Sanitary District and Shawnee Creek below the secondary treatment plant of Xenia. Summer flows in these creeks are small and therefore are not capable of assimilating present residual organic waste loads. With secondary treatment, total flows in the order of 20 cfs are needed at the present (1960) in Little Beaver Creek and Shawnee Creek with about 28 cfs in 1980, 35 cfs in 2000 and 45 cfs in 2020. Storage to supply these flows are not available because of the limited drainage area above these cities. A possible solution

TABLE 14a

LITTLE MIAMI RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Little Miami River Main Stem	Shawnee Creek	L-2	X			
Little Miami River Main Stem	Beaver Creek	L-2	X			
Shawnee Creek	Xenia	L-2	X			
Little Beaver Creek	Kettering	L-2	X			
Turtle Creek	Lebanon	L-2	X			
Lytles Creek	Wilmington	L-2	X			
East Fork Little Miami River	Batavia	K-2	X			

is piping the effluent to a larger body of water, the Little Miami River, in which event, flows of the same order would be needed in the main stem below the outfalls of these sewers. Sufficient drainage area and reservoir sites are available in the Little Miami River Basin upstream to provide storage for these flows.

Other tributary streams where low flows are negligible are Lytles Creek below the secondary treatment plant of Wilmington, and Turtle Creek below the secondary treatment plant of Lebanon. Flows in the order of 10 cfs are needed at present (1960), 14 cfs by 1980, 16 cfs by 2000 and 20 cfs by 2020.

In the East Fork of Little Miami River in the vicinity of Batavia, design flow is less than 5 cfs. At present (1960) flows in the order of 25 cfs are needed, increasing to 40 cfs by 1980, 55 cfs by 2000 and 70 cfs by 2020.

Great Miami River Basin

Present and Projected Waste Loads

Present waste loads generated are shown in Table 12b. In minor area L-1, drained by the Whitewater River, approximately 70 percent of the

present organic waste loads are due to discharges from municipalities. Approximately 70 percent occurs in Wayne County, of which Richmond is the principal city, and 25 percent occurs in Fayette County, l of which Connersville is the principal city.

In the portion of minor area L-2 drained by the Great Miami River, over 70 percent of the estimated present organic waste loads are discharged to the main stem in Butler, Warren and Montgomery Counties with approximately 60 percent originating from industrial activity. Major sources of industrial organic waste discharges from paper industries occur at West Carrollton, Franklin, Middletown and Hamilton with smaller discharges at Dayton, Miamisburg, and Excello. Major sources of municipal organic waste discharge in this reach of stream are at Dayton, Middletown and Hamilton. Other major sources of municipal waste discharges in the upper basin occur at Springfield and Fairborn on the Mad River and Piqua on the upper Great Miami River.

In other areas of the basin, the major organic waste discharge occurs in Hamilton County from a refinery.

Shown in Table 13b are the base and projected waste loads generated for the minor areas and other areas in the basin. Waste loads generated are projected to increase over fourfold in minor area L-1 and over threefold in minor area L-2 and other areas in the basin.

Water Quality Control Problems

Listed in Table 14b are the more critical areas and the approximate beginning date of the need for stream regulation for quality control after secondary treatment or further appropriate measures for pollution control that may be needed.

The major quality control problem in the basin is in the Great Miami River below Dayton. Dayton presently operates secondary treatment facilities and obtains reductions in organic constituents in the range of 85 to 90 percent, before discharging residual organics to the stream. The design summer flow of 175 cfs (not including return flows from Dayton) is not capable of assimilating present residual organic waste loads without objectionable degradation of the stream. Assuming adequate treatment total flows in the order of 585 cfs are needed at the present (1960), 740 cfs in 1980, 970 cfs in 2000 and 1400 cfs in 2020. Provision of the above flows below the Dayton sewage treatment plant outfall will maintain satisfactory conditions at Middletown and Hamilton providing all municipal and industrial organic wastes receive secondary treatment or equivalent reduction before discharge to the stream.

TABLE 14b

GREAT MIAMI RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Great Miami River-Main Stem	Sidney	L-2	X			
Great Miami River-Main Stem	Piqua	L-2	X			
Great Miami River-Main Stem	Troy	L-2		X		
Great Miami River-Main Stem	Tipp City	L-2			X	
Great Miami River-Main Stem	Vandalia	L-2		X		
Great Miami River-Main Stem	Dayton	L-2	X			
Great Miami River-Main Stem	Middletown	L-2	X			
Great Miami River-Main Stem	Hamilton	L-2	X			
Mad River	Urbana	L-2			X	
Mad River	Springfield	L-2		X		
Stillwater River	Covington	L-2	X			
Stillwater River	West Milton	L-2		X		
Greenville Creek	Greenville	L-2	X			
Sevenmile Creek	Eaton	L-2	X			
Fourmile Creek	Oxford	L-2	X			
Buckongahelas Creek	Bellefontaine	L-2	X			
W.F.Whitewater River	Connersville	L-1			X	
E.F.Whitewater River	Richmond	L-1	X			

On the main stem of the Great Miami River, upstream from the confluence of Stillwater and Mad Rivers at Dayton, indications are that stream conditions are unsatisfactory at present at Sidney and Piqua with design flows of 18 cfs and 32 cfs respectively. Below Sidney total summer flows in the order of 25 cfs are needed at present (1960), 32 cfs by 1980, 40 cfs by 2000, and 55 cfs by 2020. At Piqua total summer

flows in the order of 45 cfs are needed at present, 60 cfs by 1980, 70 cfs by 2000, and 95 cfs by 2020. At Troy, design summer flow of 40 cfs will be needed. If flows are supplied at Piqua, satisfactory stream conditions will prevail at Troy and downstream to Dayton.

In the Mad River below Urbana, design summer flow is 33 cfs. Indications are that by 2020 flow of 35-40 cfs will be required to maintain satisfactory stream conditions. Flow regulation from storage does not appear to be the solution but more intensive treatment by "polishing" ponds or holding ponds for release during periods of higher flows appears promising. Improved industrial waste treatment and control in Urbana area has resulted in improved river conditions. However, downstream at Springfield where the design summer flow is about 115 cfs, total summer flows of 120 cfs by 1980 will be needed, increasing to 140 cfs by 2000 and 160 cfs by 2020.

In the Stillwater River drainage area, unsatisfactory stream conditions exist at present below Greenville in Greenville Creek and below Covington on the Stillwater River. Improvements at Covington have resulted in improved river conditions. Total summer design flow in the order of 8 cfs exists at Greenville. However, to maintain satisfactory stream conditions 20 cfs is needed at the present (1960), increasing to 25 cfs by 1980, to 32 cfs by 2000 and to 40 cfs by 2020. If these flows can be supplied from storage in the Greenville Creek basin above Greenville, satisfactory conditions will be maintained below Covington and West Milton on the Stillwater River.

Bellefontaine on Buckongahelas Creek, Oxford on Fourmile Creek and Eaton on Sevenmile Creek, a tributary of Fourmile Creek, are located in the headwater reaches of these creeks and flows are intermittent. Below Bellefontaine, Oxford and Eaton summer flows in the order of 15 cfs are needed at present, increasing to 25 to 30 cfs by 2020. Since storage for quality control releases above these communities does not appear feasible due to limited drainage areas, a more practical solution to the pollution problem for these communities may be holding ponds for "polishing" the effluent from the sewage treatment plants, for discharge during periods of higher natural flow, and advanced waste treatment techniques.

In the Whitewater River drainage area, unsatisfactory stream conditions exist in the East Fork below Richmond where design is 2 cfs. It is estimated that 40 cfs is needed at the present (1960), 50 cfs by 1980, 70 cfs by 2000 and 90 cfs by 2020. Storage for purpose of regulation of streamflow for water quality control after secondary treatment of the organic constituents, appears to be only a partial solution as the quantity of water required does not appear to be

available. Advanced waste treatment methods will probably be required at Richmond. In the West Fork below Connersville, the design summer flow is 35 cfs. Additional flows will be required beginning in 2000 in order to augment flows to about 40 cfs.

A quality problem unrelated to population is heat discharge to streams. Major sources of heat release from thermal power generating plants to the Great Miami River occur in Montgomery County, Ohio, where a plant with a capacity of 444.1 megawatts is located at Dayton and a plant with a capacity of 414 megawatts is located at Miamisburg. In addition, plants with capacities of 58.5 and 26.5 megawatt capacities are located at Hamilton, Ohio, and a plant with a capacity of 53 megawatts is located at Piqua, Ohio. On tributary streams, a plant of 75 megawatt capacity is located in Clark County on the Mad River and plants with capacities of 40 and 50 megawatts are located in Wayne County, Indiana on the Whitewater River. There are also seven other plants with capacities of 15 megawatts or less located in the basin. Surface water is used as a source of cooling water and during periods of low flow in the stream, heat in spent cooling water is the cause of high stream temperatures in localized stream reaches. The use of cooling towers would abate the heat load to the streams, but would result in higher consumptive losses through evaporation.

Another quality problem unrelated to population, is the discharge of inorganic wastes by the steel, chemical and metal finishing industries in the basin. In order to preclude adverse effects of stream quality, these wastes should be effectively controlled at the source.

TABLES

TABLE 1a

LITTLE MIAMI RIVER BASIN

Counties in Basin

State		County	Land Area % in Basin
Ohio		Brown	25.6
"	*	Butler	0.7
"	*	Clark	26.5
"		Clermont	66.0
"	*	Clinton	83.4
"		Fayette	0.1
"	*	Greene	88.1
"		Hamilton	22.7
"		Highland	11.8
"		Madison	1.2
"	*	Montgomery	7.3
"	*	Warren	77.4

*Counties considered in economic projections of Little Miami-Great Miami River Basins.

TABLE 2a

LITTLE MIAMI RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream	Miles from Confluence with Ohio River
Little Miami River	1,755	105.5	0
East Fork	501	82	12
Todd Fork	261	35	39
Caesar Fork	239	34	51

TABLE 3a

LITTLE MIAMI RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Xenia	Greene	Ohio	8,706	9,110	10,507	10,633	12,877	20,445
Wilmington	Clinton	"	4,491	5,037	5,332	5,971	7,387	8,915
Blue Ash 1/	Hamilton	"	-	-	-	-	-	8,341
Madeira 1/	"	"	-	600	1,162	1,384	2,689	6,744
Lebanon	Warren	"	2,698	3,396	3,222	3,890	4,618	5,993
Loveland	Clermont Warren Hamilton	"	1,421	1,557	1,954	1,904	2,149	5,008

1/ Part of Cincinnati, Ohio urbanized area.

TABLE 1b

GREAT MIAMI RIVER BASIN

Counties in Basin

State		County	Land Area % in Basin
Ohio		Auglaize	13.6
"	*	Butler	89.1
"	*	Champaign	80.8
"	*	Clark	69.1
"	*	Darke	89.7
Indiana		Dearborn	15.5
"		Decatur	6.6
"	*	Fayette	92.0
"	*	Franklin	96.0
Ohio	*	Greene	7.9
"		Hamilton	33.8
"		Hardin	5.7
Indiana		Henry	6.3
Ohio	*	Logan	72.6
"		Mercer	2.7
"	*	Miami	100.0
"	*	Montgomery	92.7
"	*	Preble	100.0
Indiana		Randolph	26.5
"		Ripley	3.4
"		Rush	3.7
Ohio	*	Shelby	93.2
Indiana	*	Union	100.0
Ohio	*	Warren	22.6
Indiana	*	Wayne	100.0

*Counties considered in economic projections of Little Miami-Great Miami River Basins.

TABLE 2b

GREAT MIAMI RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream	Miles from Confluence with Ohio River
Great Miami River	5,385	170	0
Whitewater River	1,590	70	5
Fourmile Creek	320	38	38
Twin Creek	320	46	60
Mad River	656	60	85
Stillwater River	639	67	86
Loramie Creek	260	37	126

TABLE 3b

GREAT MIAMI RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Dayton	Montgomery	Ohio	116,577	152,559	200,982	210,718	243,872	262,332
Springfield	Clark	"	46,921	60,840	68,743	70,662	78,508	82,723
Hamilton	Butler	"	35,279	39,675	52,176	50,592	57,951	72,354
Kettering 1/	Montgomery	"	-	-	-	-	-	54,462
Richmond	Wayne	Indiana	22,324	26,765	32,493	35,147	39,539	44,149
Middletown	Butler	Ohio	13,152	23,594	29,992	31,220	33,695	42,115
Fairborn 1/	Greene	"	-	-	-	-	7,847	19,453
Piqua	Miami	"	13,388	15,044	16,009	16,049	17,447	19,219
Connersville	Fayette	Indiana	7,738	9,901	12,795	12,898	15,550	17,698
Sidney	Shelby	Ohio	6,607	8,590	9,301	9,790	11,491	14,663
Troy	Miami	"	6,122	7,260	8,675	9,697	10,661	13,685
Bellefontaine	Logan	"	8,238	9,336	9,543	9,808	10,232	11,424
Greenville	Darke	"	6,237	7,104	7,036	7,745	8,859	10,585
Oakwood 1/	Montgomery	"	358	1,473	6,494	7,652	9,691	10,493
Urbana	Champaign	"	7,739	7,621	7,742	8,335	9,335	10,461
Miamisburg 1/	Butler	"	-	-	-	5,544	6,329	9,893
Fairfield 2/	Butler	"	-	-	-	-	-	9,734

1/ Part of Dayton, Ohio urbanized area.

2/ Part of Hamilton, Ohio urbanized area.

TABLE 4

LITTLE MIAMI-GREAT MIAMI RIVER BASINS

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Pool Area (Acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Little Miami River					
Cowan Lake	R	720			12,000
Stonelick Lake	R	171			
Great Miami River					
Indian Lake	R	5,065			45,900
Lake Loramie	R	807			13,000
Englewood	F		312,000		
Germantown	F		106,000		
Huffman	F		167,000		
Lockington	F		70,000		
Taylorsville	F		186,000		
Acton Lake	R	625			9,400
Clark Lake	R	100			
Kiser Lake	R	386			3,261
Buck Creek 1/	F, A	1,010 2/	32,900		6,080
Brookville 1/	F, W	2,250 2/	214,700	89,300	39,100

F - Flood Control
R - Recreation
A - Low Flow Regulation
W - Water Supply

1/ Under construction.
2/ Minimum

TABLE 5a

LITTLE MIAMI RIVER BASIN

Flow Data 1/

Location	Drainage Area Above (sq. mi.)	Records Used (yrs.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Little Miami River							
Milford, Ohio	1,195	37	1,205	27	84,100	42	-
East Fork Little Miami River							
Perintown, Ohio	477	39	547	0,3	39,400	0.9	0.4

1/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprhensive Survey."

TABLE 5b

GREAT MIAMI RIVER BASIN

Flow Data[1]

Location	Drainage Area Above (sq mi.)	Records Used (yrs.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Great Miami River							
Sidney, Ohio[3]	545	46	473	8	20,700	18	7.7
Taylorsville, Ohio	1,155	44	995	30	31,400	46	30
Dayton, Ohio[1] [3]	2,513	33	2,083	78	60,900	175	89
Miamisburg, Ohio	2,718	18	2,295	148	61,800	223	-
Hamilton, Ohio[2] [3]	3,639	31	3,203	100	352,000	261	161
Loramie Creek							
Lockington, Ohio	261	34	206	2	10,400	3.2	2.2
Stillwater River							
Englewood, Ohio	646	34	571	3.7	9,980	12	4.1
Mad River							
Urbana, Ohio	157	23	140	24	8,000	33	25.3
Springfield, Ohio	485	45	481	30	30,500	115	89
Whitewater River							
Alpine, Indiana	539	31	545	14	35,000	45	-
Brookville, Indiana	1,239	41	1,274	49	81,000	82	-
East Fork Whitewater River							
Richmond, Indiana	123	10	119	0.6	14,100	2	-
Brookville, Indiana	382	4	423	12	36,100	19	-

1/ Some diversion above Dayton for municipal water supply.

2/ Low flow regulated by power plant at Hamilton and also small diversion for municipal water supply.

3/ Miami Conservancy District reservoirs have uncontrolled outlets and have no low flow regulation.

4/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey."

TABLE 6

LITTLE MIAMI-GREAT MIAMI RIVER BASINS

Economic Subarea L
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation L-1									
Indiana	Fayette	24,500	17,700						
"	Franklin	17,000	2,600						
"	Union	6,500	0						
"	Wayne	74,000	46,700						
	Subtotal	122,000	67,000	175,930		279,000		450,000	
Area Designation L-2									
Ohio	Butler	199,100	152,000						
"	Champaign	29,700	10,500						
"	Clark	131,400	94,300						
"	Clinton	30,000	11,800						
"	Darke	45,600	10,600						
"	Greene	94,600	63,600						
"	Logan	34,800	11,400						
"	Miami	72,900	40,100						
"	Montgomery	527,100	475,600						
"	Preble	32,500	5,000						
"	Shelby	33,600	14,700						
"	Warren	65,700	21,400						
	Subtotal	1,297,000	911,000	1,641,360		2,073,070		2,520,000	
Total Subarea L		1,419,000	978,000	1,817,290	1,395,000	2,352,070	1,900,000	2,970,000	2,420,000

TABLE 7

LITTLE MIAMI-GREAT MIAMI RIVER BASINS

Economic Subarea L
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation L-1													
Indiana	Fayette	8,600	4,200										
"	Franklin	5,500	1,900										
"	Union	2,300	500										
"	Wayne	28,200	10,800										
Subtotal		44,600	17,400	350.6	152	134	198	240	171	362	376	206	656
Area Designation L-2													
Ohio	Butler	70,300	31,700										
"	Champaign	10,900	3,700										
"	Clark	47,100	15,500										
"	Clinton	10,100	2,400										
"	Darke	16,800	5,600										
"	Greene	31,500	8,000										
"	Logan	12,100	3,200										
"	Miami	27,500	11,900										
"	Montgomery	198,700	77,500										
"	Preble	11,300	4,000										
"	Shelby	12,000	4,900										
"	Warren	21,500	9,400										
Subtotal		469,800	178,800	4100.5	127	122	204	165	134	350	208	146	583
Total Subarea L		514,400	195,200	4451.1	130	123	203	170	137	696	223	151	589

*In millions of 1960 dollars.
**1960 = 100

TABLE 8a

LITTLE MIAMI RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subareas	
Ohio	Brown	K-3	Ohio-Cincinnati
"	Clermont	K-2	Ohio-Cincinnati
"	Fayette	I-1	Scioto
"	Hamilton	K-2	Ohio-Cincinnati
"	Highland	I-1	Scioto
"	Madison	I-1	Scioto

TABLE 8b

GREAT MIAMI RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subareas	
Ohio	Auglaize	*	
Indiana	Dearborn	K-1	Ohio-Cincinnati
"	Decatur	Q-2	White
Ohio	Hamilton	K-2	Ohio-Cincinnati
"	Hardin	I-2	Scioto
Indiana	Henry	Q-4	White
Ohio	Mercer	*	
Indiana	Randolph	Q-4	White
"	Ripley	K-1	Ohio-Cincinnati
"	Rush	Q-2	White

*Not included in Projective Economic Study of Ohio River Basin.

TABLE 9a

LITTLE MIAMI RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Avg. (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation L-2											
Ohio	Butler	0									
"	Champaign	0									
"	Clark	1	1,500	1,500		0.075	0.075		50 e/	Wells	0
"	Clinton	4	14,560	860	13,700	1.228	0.070	1.158	84	Wells; Stone Lick; Cowan Creek and Little East Fork	0
"	Darke	0									0
"	Greene	7	32,500	32,500	0	3.739	3.739		115	Wells	0.6
"	Logan	0									
"	Miami	0									
"	Montgomery	0									
"	Preble	0									
"	Shelby	0									
"	Warren	6	21,190	21,190	0	2.465	2.465	0	117	Wells	
	Subtotal	18	69,750	56,050	13,700	7.507	6.349	1.158	108		0.6
Other Areas in Basin											
Ohio	Brown	1	150		150	0.012		0.012	80	Solomon River and Reservoir	0
"	Clermont	7	40,780	34,430	6,350	2.568	2.128	0.440	63	Wells and East Fork Little Miami	0
"	Hamilton	1	14,000	14,000		1.570	1.570		112	Wells	0.9
"	Highland	1	1,050	1,050		0.100	0.100		95	Wells	0
	Subtotal	10	55,980	49,480	6,500	4.250	3.798	0.452	76		0.9
	TOTAL	28	125,730	105,530	20,200	11.757	10.147	1.610	94		1.5

(e) Estimated

TABLE 10a

LITTLE MIAMI RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Use (gpcd)	Total Use (mgd)	Pop. Served	Use (gpcd)	Total Use (mgd)	Pop. Served	Use (gpcd)	Total Use (mgd)	Pop. Served	Use (gpcd)	Total Use (mgd)
Area Designation L-2												
From Central Supplies	69,750	108	7.5	99,000	118	11.7	130,400	126	16.4	160,400	131	21.0
Industrial			0.6			1.0			1.5			2.2
Subtotal			8.1			12.7			17.9			23.2
Other Areas in Basin												
From Central Supplies	55,980	76	4.3	79,500	89	7.1	104,700	94	9.8	128,800	98	12.6
Industrial			0.9			1.5			2.2			3.3
Subtotal			5.2			8.6			12.0			15.9
Little Miami River Basin												
From Central Supplies Total	125,730	94	11.8	178,500	105	18.8	235,100	111	26.2	289,200	116	33.6
Industrial Total			1.5			2.5			3.7			5.5
GRAND TOTAL			13.3			21.3			29.9			39.1

TABLE 9b

GREAT MIAMI RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Avg. (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation L-1											
Indiana	Fayette	1	20,000	20,000		4.000	4.000		200	Wells	1.2
"	Franklin	3	4,040	4,040		0.491	0.491		122	Wells	1.0
"	Union	1	1,700	1,700		0.150	0.150		88	Wells	0.1
"	Wayne	7	56,350	56,350*		11.440	3.813	7.627	203	Wells and Whitewater River	2.4
	Subtotal	12	82,090	82,090		16.081	8.454	7.627	196		4.7
Area Designation L-2											
Ohio	Butler	9	150,295	149,095	1,200	17.238	17.183	0.055	115	Wells and Little Four Mile Creek	42.0
"	Champaign	3	12,670	12,670		1.632	1.632		129	Wells	5.0
"	Clark	6	99,055	99,055		14.767	14.767		152	Wells	1.0
"	Clinton	0									0
"	Darke	6	16,875	6,375	10,500	2.180	0.680	1.500	129	Wells and Greenville Creek	1.0
"	Greene	2	23,200	23,200		2.060	2.060		87	Wells	2.0
"	Logan	7	19,375	19,375		3.002	3.002		155	Wells	0.2
"	Miami	9	49,265	29,285	19,980	6.732	3.332	3.400	137	Wells and Miami River	2.0
"	Montgomery	12	428,715	428,715		62.040	62.040		148	Wells	47.1
"	Preble	8	12,825	12,825		1.290	1.290		101	Wells	0
"	Shelby	5	18,195	18,195		1.487	1.487		82	Wells	0.1
"	Warren	2	11,900	11,900	0	1.100	1.100	0		Wells	4.5
	Subtotal	69	842,370	810,690	31,680	113.528	108.573	4.955	135		104.9
Other Areas in Basin											
Ohio	Auglaize	2	2,945	2,945		0.440	0.440		149	Wells	0.1
"	Hamilton	2	6,955	6,955		0.480	0.480		69	Wells	50.0
Indiana	Randolph	1	1,140	1,140		0.080	0.080		70	Wells	0
	Subtotal	5	11,040	11,040		1.000	1.000		91		50.1
	TOTAL	86	935,500	903,820	31,680	130.609	118.027	12.582	140		159.7

*Combined ground and surface source.

TABLE 10b

GREAT MIAMI RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Use (gpcd)	Total Use (mgd)	Pop. Served	Use (gpcd)	Total Use (mgd)	Pop. Served	Use (gpcd)	Total Use (mgd)	Pop. Served	Use (gpcd)	Total Use (mgd)
Area Designation L-1												
From Central Supplies	82,090	196	16.1	132,100	203	26.8	210,000	208	43.6	358,000	213	76.3
Industrial			4.7			7.8			12.5			20.3
Subtotal			20.8			34.6			56.1			96.6
Area Designation L-2												
From Central Supplies	842,370	135	113.5	1,196,000	141	168.6	1,575,000	147	231.5	1,938,000	153	296.5
Industrial			104.9			171.0			254.0			382.0
Subtotal			218.4			339.6			485.5			678.5
Other Areas in Basin												
From Central Supplies	11,040	91	1.0	15,700	106	1.7	20,700	116	2.4	25,400	124	3.2
Industrial			40.1			65.4			97.0			146.0
Subtotal			41.1			67.1			99.4			149.2
Great Miami River Basin												
From Central Supplies Total	935,500	140	130.6	1,343,800	147	197.1	1,805,700	154	277.5	2,321,400	162	376.0
Industrial Total			149.7			244.2			363.5			548.3
GRAND TOTAL			280.3			441.3			641.0			924.3

TABLE 12a

LITTLE MIAMI RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation L-2						
Ohio	Butler	0				
"	Champaign	0				
"	Clark	1	1,505	Little Miami River	1,505	300
"	Clinton	3	14,175	Second Crk.,Todd Fk.,Lytles Crk.	14,175	240
"	Darke	0				
"	Greene	4	28,040	Massie Crk.,S.Fk.Caesar Crk., Shawnee and Gladys Run, Little Miami River	28,040	11,320
"	Logan	0				
"	Miami	0				
"	Montgomery	1	36,460	Beaver Creek	36,460	1,440
"	Preble	0				
"	Shelby	0				
"	Warren	7	12,960	Turtle Crk., Muddy Crk., Dry Run, Clear Creek, Little Miami	12,960	
	Subtotal	16	93,140		93,140	13,300
Other Areas in Basin						
Ohio	Brown	1	150	East Fork	150	
"	Clermont	4	12,890	East Fork L.Miami and Little Miami	12,890	2,000
"	Hamilton	1	4,500	Little Miami River	4,500	3,000
"	Highland	1	1,020	East Fork Little Miami River	1,020	
	Subtotal	7	18,560		18,560	5,000
	TOTAL	23	111,700		111,700	18,300

*NOT to be interpreted as waste loads to the stream.

TABLE 13a

LITTLE MIAMI RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation L-2				
Domestic and Commercial	93,140	132,300	174,200	214,200
Industrial	13,300	15,900	27,000	40,700
Subtotal	106,440	148,200	201,200	254,900
Other Areas in Basin				
Domestic and Commercial	18,560	26,400	34,700	42,700
Industrial	5,000	8,200	12,100	18,200
Subtotal	23,560	34,600	46,800	60,900
Little Miami River Basin				
Domestic and Commercial Total	111,700	158,700	208,900	256,900
Industrial Total	18,300	24,100	39,100	58,900
GRAND TOTAL	130,000	182,800	248,000	315,800

*NOT to be interpreted as waste loads to the stream.

TABLE 12b

GREAT MIAMI RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation L-1						
Indiana	Fayette	1	17,700	West Fork Whitewater River	17,700	6,700
"	Franklin	2	3,265	West Fork Whitewater River - Harper Branch	3,265	1,200
"	Union	1	1,745	Silver Creek	1,745	200
"	Wayne	4	48,675	East and West Fork Whitewater - Nolands Fork	48,675	28,800
	Subtotal	8	71,385		71,385	36,900
Area Designation L-2						
Ohio	Butler	4	124,290	Great Miami R.and Four Mile Crk.	124,290	328,000
"	Champaign	2	11,920	Nettle Creek, Dugan Run	11,920	21,300
"	Clark	2	86,825	Honey Creek, Mad River	86,825	22,400
"	Clinton	0				
"	Darke	6	17,985	Stillwater R., E.F.Whitewater	17,985	8,300
"	Greene	1	19,455	Mad River	19,455	69,350
"	Logan	4	16,005	Great Miami R.,Mad R.,Possum Run	16,005	3,300
"	Miami	7	45,820	Stillwater R.,Miami R.,Ballinger Run	45,820	58,550
"	Montgomery	12	314,670	Great Miami R.,Stillwater R., Twin Crk.,Wolf Crk.	314,670	295,000
"	Preble	5	10,960	Seven Mile Crk.,Four Mile Crk., Twin Creek, Stillwater River	10,960	2,300
"	Shelby	2	15,640	Wolf Creek, Great Miami River	15,640	7,700
"	Warren	1	7,915	Miami River	7,915	65,600
	Subtotal	46	671,485		671,485	881,800
Other Areas in Basin						
Ohio	Auglaize	1	2,190	Great Miami River	2,190	
"	Hamilton	1	3,880	Whitewater River	3,880	90,000
	Subtotal	2	6,070		6,070	90,000
	TOTAL	56	748,940		748,940	1,008,720

TABLE 13b

GREAT MIAMI RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation L-1				
Domestic and Commercial	71,385	114,900	182,700	311,200
Industrial	36,900	61,300	98,200	159,000
Subtotal	108,285	176,200	280,900	470,200
Area Designation L-2				
Domestic and Commercial	671,485	953,500	1,255,700	1,544,400
Industrial	881,800	1,437,400	2,134,000	3,209,800
Subtotal	1,553,285	2,390,900	3,389,700	4,754,200
Other Areas in Basin				
Domestic and Commercial	6,070	8,600	11,400	13,700
Industrial	90,000	146,700	217,800	327,600
Subtotal	96,070	155,300	229,200	341,300
Great Miami River Basin				
Domestic and Commercial Total	748,940	1,077,000	1,449,800	1,869,300
Industrial Total	1,008,700	1,645,400	2,450,000	3,696,400
GRAND TOTAL	1,757,640	2,722,400	3,899,800	5,565,700

*NOT to be interpreted as waste loads to the stream.

OHIO RIVER BASIN FRAMEWORK STUDY

LITTLE MIAMI - GREAT MIAMI RIVER BASINS
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 8.1

LICKING-KENTUCKY-SALT RIVER BASINS

Subbasin Area
No. 9

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I SUMMARY

General

Transbasin diversions for water supply are already a reality in several locations in this area. They may well become a necessary provision for augmenting flows for waste dilution as well. Various problem solutions suggested in this sub-basin report should be considered singly as well as in groups in more detailed studies, since it may be possible to save on construction costs and provide several benefits via the same project.

Licking River Basin

Municipal and Industrial Water Supply Problems

Major municipal water use in the basin occurs in the extreme lower portion of the Licking River in pool from Markland Dam on the Ohio River. Other large water use occurs at Mount Sterling, Paris and Cynthiana in the South Fork drainage area. Practically all water supplies in the basin are obtained from surface sources. Industrial water is for the most part supplied from municipal systems.

Based on available data of dependable yields from existing sources, Mount Sterling and Flemingsburg should be planning now to develop additional sources of supply and by 1980, Morehead should be looking to expand its present source of supply. All three communities are located in the headwater region of tributary streams and alternate solutions to their problems are development of additional local impoundments, development of a source of supply in a large stream capable of meeting projected needs, or in the case of Mount Sterling, allocation of water supply storage in Federal reservoirs in either the Licking or Kentucky River Basins. Paris and Cynthiana apparently have sufficient storage to meet projected needs although problems with taste and odor will continue and require intensified efforts to produce water of acceptable quality. Alternate solutions to this problem could be off-stream storage in impoundments to be filled during periods of higher flows or allocation of water supply storage in Federal reservoirs.

Water Quality Control Problems

Major problem areas in the Licking River Basin presently exist in the lower portion of the basin in the reach of the Licking River in pool from Markland Dam on the Ohio River and in the central portion of the basin, in the South Fork drainage area and in Triplett Creek.

The problem in the reach of the Licking River in pool from Markland Dam is taste and odor primarily caused by nutrients in the water promoting algal growths at lower flows. In the South Fork drainage area, stream conditions during low flow are unsatisfactory in Strodes Creek below Winchester, Stoner Creek below Paris, Hinkston Creek below Mount Sterling and the South Fork below Cynthiana. Stream conditions in Triplett Creek below Morehead are unsatisfactory at the present.

Kentucky River Basin

Municipal and Industrial Water Supply Problems

Major municipal water use in the basin occurs at Lexington with Frankfort, Danville and Winchester being the next largest water using communities. Although Winchester, Kentucky is in the Licking Drainage Basin its water supply source is the Kentucky River. Most of the water in the basin is obtained from surface sources and the majority of industrial water is supplied by municipal systems.

Lexington obtains most of its water from the Kentucky River and its use is approaching the 1 day - 30 year low stream flow. Ground water of suitable quality does not appear to be available in dependable quantities to meet projected needs so continued use of surface water is indicated. The best solution appears to be allocation of water supply storage in the Federal reservoirs being proposed in the Kentucky River Basin upstream of Lexington's intake. Even if ground water is not used for municipal supplies at Lexington, the resource is nevertheless valuable and has potential for development for supplementary municipal and other uses. Inasmuch as the limestone aquifers in the Louisville area are especially susceptible to contamination from surface sources because of its cavernous nature, special and continuing precautions should be taken to protect the aquifer from further contamination and to abate present practices that result in contamination. Frankfort and Winchester using water from the Kentucky River apparently have ample supplies throughout the study period.

Water Quality Control Problems

Major quality control problems exist in the Elkhorn Creek area where the city of Lexington discharges treated wastes into the South Fork and Georgetown discharges treated wastes into the North Fork. Since storage to provide enough streamflow for assimilation of residual organic wastes does not appear to be available, an alternate solution to this problem is the construction of an outfall sewer to the Kentucky River where the needed flows can be made available from proposed upstream reservoirs.

Streams where unsatisfactory conditions presently exist during periods of low flow are Otter Creek below Richmond, Jessamine Creek below Nicholasville, Glenns Creek below Versailles and by 1980 Eagle Creek below Owenton. Since these communities are located in headwater areas and flow regulation does not appear to be a feasible solution, transmission of effluents after secondary treatment to the Kentucky River is probably the most likely solution.

Other areas where low streamflows are not adequate to assimilate residual wastes and storage does not appear to be available, are Clarks Run below Danville, White Oak Creek below Lancaster, Logan Creek below Stanford, and Silver Creek below Berea. At these locations intensive treatment appears to be indicated.

In the upper basin, in the North Fork of the Kentucky River, in addition to unsatisfactory stream conditions below Hazard due to residual organic discharges when streamflow is low, problems of high sulfate and chloride concentrations exist as the result of runoff from mine drainage and brine pits from oil production. The organic problem can be abated by discharges from proposed reservoirs, but the discharge of mineral pollutants must be controlled at the source.

Salt River Basin

Municipal and Industrial Water Supply Problems

There are no major water using communities in the basin and total industrial water use is nearly as great as the municipal demand. Practically all municipal and industrial water is obtained from surface sources. Expansion of the Louisville urban area into the basin has resulted in transbasin diversion of water from the Ohio River into the Salt River Basin.

Many of the communities and industrial installations in the basin are encountering water supply problems during low flow periods. As the total water supply requirements are relatively small and dispersed throughout the basin, it is beyond the scope of this report to define and suggest solutions for these problem areas and further detailed study is indicated.

Water Quality Control Problems

Quality control problems in the streams of the basin are due to the discharge of organics by municipalities and industries. Secondary treatment of wastes by municipalities, and improved plant housekeeping and treatment of inseparable wastes by the distilling industry in the basin are required.

However, even with intensive treatment, stream conditions are unsatisfactory at low flows in the Beech Fork below Bardstown, the Rolling Fork below New Haven, Road Run Creek below Springfield, and

the main stem of the Salt River below Harrodsburg and Shepherdsville. Low flow regulation or other appropriate methods of abatement are indicated in these stream reaches.

In the Floyds Fork area, urban growth of the city of Louisville into the basin is the source of organic pollution in streams in this area. Even with collection and treatment increased flow will be needed to assimilate residual wastes.

II DESCRIPTION OF STUDY AREA

The Licking, Kentucky, and Salt River Basins comprise nearly a third of the land area of the Commonwealth of Kentucky. As the basins are all entirely within the Commonwealth of Kentucky and exhibit many similar physical characteristics, as well as a similar economic base, they are carried in a single section of this report.

Licking River Basin

Location and Boundaries

The Licking River Basin, easternmost of the river basins considered in this section of the report, is located entirely within the eastern portion of the Commonwealth of Kentucky. The river rises in southeastern Kentucky and flows generally northeasterly to its junction with the Ohio River opposite Cincinnati, Ohio, 469 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is 3,670 square miles which is approximately 9 percent of the land area of the State and includes all or portions of the 21 counties listed in Table 1a. The basin is shaped much like a trapezoid with the main axis about 130 miles in length and the short axis about 60 miles in width. The length of stream is about 320 miles and the basin extends north to Covington and Newport; south past Salyersville; east beyond Flemingsburg and Morehead; and west to Winchester.

The main tributaries comprising the Licking River system are shown in Table 2a.

Physical Features

The Licking River drainage area is entirely south of the glaciated portion of the Ohio River Basin and physical features of the basin are generally the result of geologic strata exposed by differential erosion following the broad upwarping of the Paleozoic Era known as the Cincinnati Arch. The Licking River Basin exhibits four distinct physiographic types. The river rises in the Eastern Coal Field region of the Kanawha section of the Appalachian Plateau, which has narrow ridges and crooked steep-sided valleys. It flows through the Knobs and the Outer Blue Grass regions. The South Fork

drains a portion of the Inner Blue Grass region of the Interior Low Plateau. The Knobs is an area of conical hills with rather broad valleys. The Outer Blue Grass is rather gently rolling except where the streams have entrenched themselves into deep valleys. The Inner Blue Grass region is gently rolling upland.

There are no natural lakes in the basin. Artificial reservoirs include six bodies of water constructed for recreation purposes with two lakes serving also as water supply reservoirs. Construction of multiple-purpose reservoirs at sites on the Licking River at Cave Run and Falmouth is planned by the Corps of Engineers.

Climate

The average annual precipitation in the basin is approximately 42 inches, generally well distributed throughout the year.

Average minimum temperature is approximately 34°F in January and average maximum temperature is approximately 75°F in July. The frost-free season varies from approximately 176 days in the mountains and Knobs region to 187 days in the Blue Grass region.

Principal Communities and Industries

Agriculture maintains an important position in the economy of much of the basin. In many areas, the hilly topography prevents cropping except in the narrow flood plains and much of the basin is given over to permanent pasture, woodland, or just idle land.

There is little coal mining in the basin but there is some crude oil production.

The principal communities in the basin are located at the mouth of the river and along the South Fork of the Licking River. In Newport and Covington, the communities at the mouth of the river, is found a diversification of industry typical of that found in large metropolitan areas. In addition, there is one major basic steel producing plant located in Newport. Industry in the communities located in the South Fork drainage area produce apparel; fabricated and plated metals; automotive components and clay and concrete building products.

Listed in Table 3a are the principal cities, all in the Commonwealth of Kentucky, and their populations from 1910 to 1960.

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OHIO RIVER BASIN COMPREHENSIVE SURVEY. VOLUME V. APPENDIX D. WA--ETC(U)
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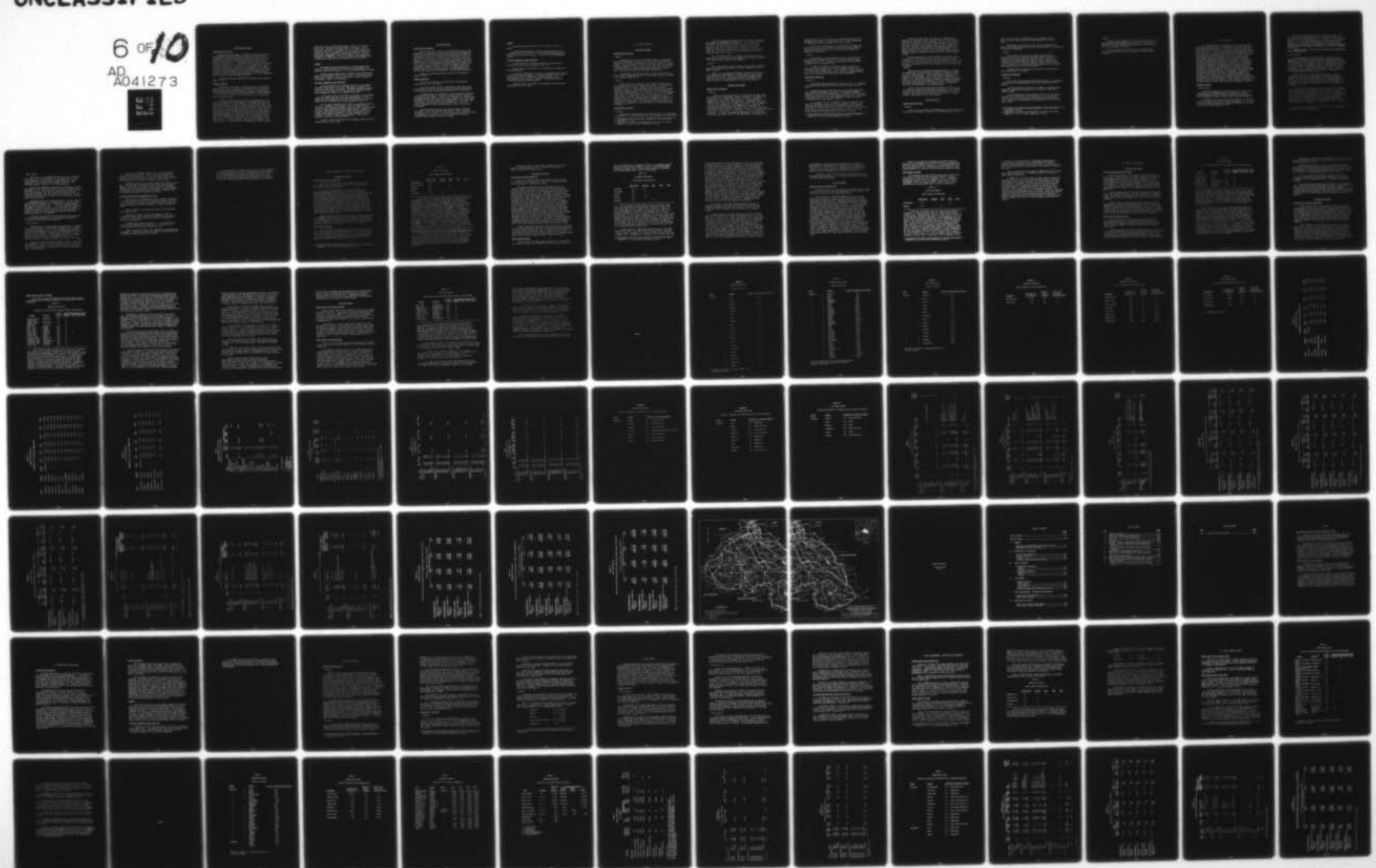

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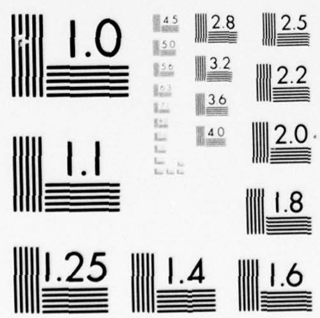


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Kentucky River Basin

Location and Boundaries

The Kentucky River Basin is located in the central portion of the Commonwealth of Kentucky and is bounded on the east by the Licking River Basin and on the west by the Salt River Basin. The Kentucky River rises in southeastern Kentucky and flows 427 miles generally northwesterly to its confluence with the Ohio River at Carrollton, Kentucky, 545 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is 6,940 square miles, all in Kentucky, and comprises 17 percent of the land area of the commonwealth and covers all or parts of the 38 counties listed in Table 1b. The basin is approximately 175 miles long and varies in width from 30 miles in the lower portion to 50 miles in the headwater region. The basin extends southeast beyond Whitesburg, south beyond Manchester, east to Winchester and west beyond Danville.

The main tributaries comprising the Kentucky River system are shown in Table 2b.

Physical Features

The Kentucky River Basin is entirely south of the glaciated portion of the Ohio River Basin. As described in the Licking River Basin, physical features are generally a result of the geological strata exposed by differential erosion following the broad upwarping in the Paleozoic Era known as the Cincinnati Arch. Erosion of the axis of this arch structure resulted in gorge sections where there was considerable uplift.

The South, Middle and North Forks of the Kentucky River all rise in the Eastern Coal Field region of the Kanawha section of the Appalachian Plateau. The South and North Forks join at Beattyville to form the Kentucky River which flows northward across the Lexington Plain section of the Interior Low Plateau province. The river flows successively through the Knobs region, the Outer Blue Grass region, and the Inner Blue Grass region to its confluence with the Ohio River. The Blue Grass region is a fertile tableland located approximately 1000feet above mean sea level and provides the richest agricultural land in the Commonwealth of Kentucky. This area is gently rolling, almost denuded of woodland and was originally blanketed with rich, often phosphatic limestone topsoil. Near the outer fringe of this zone, the soil is thinner and poorer and generally relief is somewhat

sharper due to the increasing percentage of shale in the bedrock of the area. There are no natural lakes in the basin. Of the reservoirs constructed in the basin, one is for water supply and recreation, one is for recreation only, one serves as a source for hydroelectric power generation, and Buckhorn Reservoir, a Federal multipurpose impoundment, is for flood control, water supply and recreation. In addition, the Corps of Engineers are studying sites on Eagle Creek, Red River and at Booneville on the South Fork.

Climate

The average annual precipitation in the basin varies from about 44 inches at Lexington to 48 inches in the mountains in the headwater region and is generally well distributed throughout the year.

Average minimum temperatures at Lexington range from approximately 32°F in January to about 75°F in July. The frost-free season varies from 180 days in the Blue Grass region to about 166 days in the headwater region in the mountains.

Principal Communities and Industries

Agriculture maintains an important position in the economy of the basin, particularly in the Blue Grass regions located in the central and lower part of the basin. Raising of thoroughbred horses and livestock and crops, such as corn and hay and pasture, occupy large acreages and tobacco is an important cash crop.

In the upper portion of the basin, coal mining is an important extractive industry and gas and oil are also produced. In the middle and lower portions of the basin, mining activity is confined almost wholly to crushed stone and sand and gravel production.

The principal communities are located in the middle portion of the basin. Lexington is the largest city in the basin and its industry produces business machinery, textiles, tobacco products, meat products, glass lamps and fabricated metal products. Industry in Frankfort produces distilled spirits, apparel and footwear and in Richmond glass lamps are produced. In other communities in this portion of the basin, industry produces apparel, rubber goods, glassware, electrical wiring and devices.

Listed in Table 3b are some of the principal cities, and their populations from 1910 to 1960.

Salt River Basin

Location and Boundaries

The Salt River Basin lies in the northcentral portion of the Commonwealth of Kentucky. The Salt River rises in Boyle County and flows due north about 40 miles before turning abruptly westward to flow another 75 miles to its junction with Rolling Fork, then north again for 12 miles where it enters the Ohio River near Louisville, Kentucky, 630 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is about 2,900 square miles, comprising about 7 percent of the Commonwealth and covering all or parts of the 15 counties listed in Table 1c. The basin is roughly circular in shape with a diameter of about 63 miles. The basin extends from suburban Louisville on the north, nearly to Elizabethtown on the west and near Danville and Harrodsburg on the east (See Figure 9-1).

The main tributaries comprising the Salt River system are shown in Table 2c.

Physical Features

The Salt River Basin is entirely south of the glaciated portion of the Ohio River Basin.

The river rises in the Blue Grass region of the Interior Low Plateau and flows through the Knobs region to Anderson County, where it then flows across the Mississippian Plateau to the Ohio River.

The Knobs region is a narrow belt of hills generally less than 10 miles wide that marks the transition between the Blue Grass and the Mississippian Plateau. Typically, the topography is conical hills separated by broad, relatively flat stream valleys. The conical hills are capped by resistant limestone and sandstone; the hill slopes and broad valleys are underlain by easily eroded shale. Runoff is usually rapid and the small springs generally go dry in periods of dry weather.

The Mississippian Plateau surrounds the massive limestones and shales of the Blue Grass and Knobs regions. Here the bedrock is primarily shale with some fine grained sandstone and limestone strata. The topography is of moderate relief with some steep slopes and resistant ledges formed by the shale outcrops.

Climate

The average annual precipitation in the basin is about 41 inches.

Average minimum temperatures range from approximately 35°F in January to about 77°F in July. The frost-free season varies from about 176 days in the Knobs region to 187 days in the Mississippian Plateau.

Principal Communities and Industries

The agriculture of the basin is devoted to stock and crop raising with tobacco being an important cash crop.

Mining activity is confined to the production of crushed stone and sand and gravel.

The largest community in the basin is Harrodsburg where industry produces flat glass and apparel. The primary industry in the basin is distilling located at Bardstown, Lebanon and many of the other communities in the basin. Industry in Shelbyville produces aluminum castings and tobacco products.

Listed in Table 3c are some of the principal cities and their populations from 1910 to 1960.

III WATER RESOURCES

Licking River Basin

Surface Water Resources

Quantity

Streamflow in the basin at the present time is not materially affected by impoundments. Reservoirs constructed in the basin are used for water supply or recreational use and are located on tributary streams. Cave Run Reservoir, located on the main stem of the Licking River above Farmers, is under construction by the Corps of Engineers for flood control, low flow regulation and recreation. Shown in Table 4 are pertinent data regarding these impoundments.

The streams in the basin have poor low flow characteristics. Table 5 shows stream data excerpted from hydrology statistics prepared by the Corps of Engineers.1/

Quality

Surface waters of the Licking River contain moderate amounts of dissolved solids with an average concentration of 125 mg/l and an average hardness of 90 mg/l. Generally, dissolved solids and hardness increase with lower sustained flows. In addition to natural variations, changes in quality are often the result of domestic and industrial wastes especially in the streams in the South Fork drainage area, several of the main stem minor tributaries, and in the extreme lower reach of the main stem. Quality in the main stem of the Licking River is at the present virtually unaffected by domestic and industrial pollution. Mine drainage is not presently a factor in water quality in the basin. Oil field wastes and brines affect some streams in the headwaters of the tributaries in the upper portion of the basin.

Ground Water Resources

Quantity

Ground water resources have been reported by the U. S. Geological Survey2/ and the following discussion has been condensed from their report.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The water bearing consolidated rocks in the basin showing the most promise of development are sandstone in the southern third of the basin in the Eastern Coal Field region. Water is derived principally from fractures and joints at shallow depths, and at greater depths, where joints are fewer, from coarse textured sandstone. Some wells yield as much as 500 gpm in the upper strata and as much as 900 gpm in the lower strata although more typical yields are about 25 to 50 gpm.

Alluvium along the lower 20 miles of the river should be a good source of ground water but development has been small due probably to the availability of ample surface supplies.

Quality

Water from bedrock formations range up to 175 mg/l of hardness and iron is generally high enough to require treatment for public water supplies.

Water in the unconsolidated deposits along the Ohio River is very hard, varying from 250 mg/l to 340 mg/l and has objectionable concentrations of iron. Data are not available on samples taken from the alluvium along the Licking River but undoubtedly results would be similar to those shown for the Ohio River alluvium.

Kentucky River Basin

Surface Water Resources

Quantity

There are several reservoirs in the Kentucky River Basin which have an effect on streamflows. Buckhorn Reservoir on the Middle Fork of the Kentucky River was constructed by the Corps of Engineers primarily for flood control and recreation. Herrington Lake in the lower portion of the Dix River subbasin was constructed by a public utility for the production of hydroelectric power. Other impoundments that have been constructed by the Commonwealth of Kentucky for recreation use are Elmer Davis and Corinth, with the latter used also as a source of water supply. A reservoir, on Carr Fork is under construction by the Corps of Engineers for flood control, low flow regulation and recreation. Pertinent data regarding impoundments in the Kentucky River Basin are shown in Table 4. The main stem of the Kentucky River

consists of a series of slack water pools extending about 260 miles upstream from the mouth. A minimum depth of six feet is maintained for navigation purposes throughout this reach of river.

The low flow characteristics of the streams in the basin are generally poor making it necessary to construct surface storage to provide sufficient storage for year-round supplies of water for medium-sized communities.

Quality

Surface waters in the Kentucky River Basin contain amounts of dissolved solids averaging about 200 mg/l and are moderately hard, averaging about 90 mg/l. Generally, dissolved solids and hardness increase with lower sustained flows.

In addition to natural variations, changes in quality are often the result of domestic and industrial wastes especially in the Elkhorn Creek drainage area. In the headwater region, especially in the North Fork tributary area, severe acid mine drainage problems exist as well as high chlorides from oil well operations.

Ground Water Resources

Quantity

Ground water resources have been reported by the U. S. Geological Survey 1/ and the following discussion has been condensed from their report.

The water bearing consolidated rocks in the basin showing the most promise of development are located in the extreme headwater region of the North Fork drainage area in the Eastern Coal Field region although consolidated rocks in the remaining portion of the upper third of the basin and in the Blue Grass region may be expected to yield intermediate quantities of water to wells.

In the upper third of the basin including the headwater region, bedrock is sandstone. Water is derived principally from fractures and joints at shallow depths and at greater depths where joints are fewer and the sandstone has a coarser texture. Some wells yield as much as 500 gpm in the upper strata and as much as 900 gpm in the lower strata although more typical yields are about 25 to 50 gpm.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

In the Blue Grass region, the bedrock is limestone with numerous shale partings in the Outer region and in the Inner region limestone with numerous solution openings. Because of the soluble nature of the limestone, springs are numerous, many with relatively high flows, some more than 500 gpm. Wells drilled in limestone in the Outer Blue Grass region generally yield adequate supplies for domestic use and in a few areas yield as much as 100 gpm. In the Inner Blue Grass region, wells drilled in limestone generally yield adequate supplies for domestic use and a few wells yield as much as 400 gpm.

Alluvium deposits are fairly extensive in the lower 20 miles of the valley of the Kentucky River, but there has been no large withdrawals of water in the area and hydrologic data are scarce. There are indications from sand and gravel operations in the area that the materials are permeable and that the potential exists for ground water development.

Quality

Water from bedrock sandstone formations range up to 150 mg/l in hardness and iron is generally high enough to require treatment for public water supplies. Brine is commonly encountered in strata underlying the fresh water. Water from limestone formations is generally very hard, ranging up to 800 mg/l, and is high in dissolved solids. Iron chloride and hydrogen sulphide are generally present in undesirable quantities and because of the direct connection between the surface and openings in the limestone aquifer, contamination has been a serious problem in the Lexington area.

Water in the unconsolidated deposits along the Ohio River is very hard and generally has undesirable quantities of iron. Samples of ground water from the alluvium along the Kentucky River are not available, but undoubtedly this water would be similar in chemical content to water from the Ohio River alluvium.

Salt River Basin

Surface Water Resources

Quantity

While there are a number of impoundments in the Salt River Basin, constructed for recreation purposes by the Commonwealth of Kentucky,

these reservoirs have no pronounced effect on streamflow in the basin. Pertinent data regarding these impoundments are shown in Table 4.

The streams in the basin have poor low flow characteristics. Table 5 shows stream data excerpted from hydrology statistics prepared by the Corps of Engineers.1/

Quality

Surface waters in the Salt River Basin contain moderate amounts of dissolved solids with an average concentration of about 200 mg/l and an average hardness of about 150 mg/l. Generally, dissolved solids and hardness increase with lower sustained flows. In addition to natural variations, changes in quality are often the result of domestic and industrial waste discharges, primarily organics from communities and the distilling industry.

Inorganic waste discharges from coal mines or oil production are not a problem in the basin.

Ground Water Resources

Quantity

Ground water resources have been reported by the U. S. Geological Survey2/ and the following discussion has been condensed from their report.

The bedrock underlying the Salt River Basin is limestone interbedded with shale and is a limited source of water for other than domestic needs.

The alluvium along the lower reaches of the Salt River and its tributary, the Rolling Fork, is a potential source of ground water although there has been very little development of these resources to date. Possibly the alluvium may be fine grained and will yield only small supplies.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

Quality

There are no data available on the chemical characteristics of water from bedrock formations in the Salt River Basin, but undoubtedly the characteristics of these waters would be similar to those in the Kentucky River Basin.

Water from the alluvium is probably very hard, similar in chemical characteristics to that of the water from the Kentucky River Basin.

IV THE ECONOMY

The Licking-Kentucky-Salt subarea of the Projective Economic Study lies entirely within the Commonwealth of Kentucky, covering the middle and upper reaches of the Licking River, the middle and upper reaches of the Kentucky River, and the middle and upper reaches of the Salt River. To facilitate estimates of future water requirements and waste loads derived from the projected economy, the area is divided into four minor areas, M-1, M-2, M-3, and M-4, and correlated as nearly as possible with the intra-area hydrology. Minor area M-1 generally coinciding with the Salt River Basin includes the eight western counties in the subarea. The boundaries of minor areas M-2 and M-4 generally coincide with the Kentucky River Basin boundaries. Minor area M-2 includes the twelve middle counties in the subarea and minor area M-4 includes the eleven southeastern counties. The boundaries of minor area M-3 generally coincide with the boundaries of the Licking River Basin and includes the twelve northeastern counties in the subarea. The portion of the subarea lying within the region designated as Appalachia, includes in minor area M-2, the four southern counties of Clark, Garrard, Lincoln, and Madison, all of minor area M-3 excluding the five northern counties of Bourbon, Harrison, Nicholas, Pendleton, and Robertson, and all of minor area M-4. The counties in each minor area are listed in Tables 6 and 7 and shown on Figure 9-1, page 9-67.

Economic Profiles

Minor Area M-1

In 1960, the population of minor area M-1 was 119,000, and the largest city was Harrodsburg with a population of 6,000. Average personal per capita income in this minor area amounted to $1,151, compared to $1,322 for Kentucky and $1,850 for the Nation.

The total value of farm products sold amounted to $53 million in 1959, 54 percent of which were livestock products. In 1954, the total value of farm products sold amounted to $43 million. A total of 1,600 acres were irrigated in 1959.

Manufacturing employment manifested an average annual growth rate of 5 percent between 1950 and 1960. Between 1958 and 1964, the number of establishments employing 100 workers or over increased from 11 to 18. The most important industries are food processing, machinery (including electrical machinery), printing and allied products, and other durables. Thermal electric generating plants are located at Burgin and Tyrone with capacities of 293 and 137 megawatts respectively.

Mining activity is confined to the production of crushed stone and to sand and gravel.

Minor Area M-2

The population in minor area M-2 was 311,700 in 1960, 42.5 percent of which resided in Fayette County, a designated Standard Metropolitan Statistical Area. Four large cities are located in the area; Lexington in Fayette County being the largest with a population of 62,800; Frankfort in Franklin County with a population of over 18,000; Richmond in Madison County with a population of 12,000; and Winchester in Clark County with a population of 10,000. Average personal per capita income was $1,812 in Fayette County and $1,313 in the remaining area of minor area M-2.

Agriculture was the most important employment category. Between 1954 and 1959, the total acres in farm land increased by 80,000, and total value of farm products sold increased about $15 million, to a total of $92 million by 1959, field crops accounting for 53 percent of the total. However agricultural employment decreased 9,720 between 1950 and 1960. By 1959, 2,200 acres were irrigated.

There has been a significant change in the number of manufacturing establishments in this minor area. Between 1958 and 1964, the total number of plants employing 100 or more workers increased from 31 to 46, Fayette County accounting for 11 of the 15 new establishments. Manufacturing employment in 1960 (18,100) was double that of 1950. The most important industries in the area are machinery (including electrical machinery), food processing, apparel, and other nondurables. A thermal electric generating plant is located at Winchester and has a capacity of 196 megawatts.

Mining activity is almost wholly confined to crushed and broken stone and sand and gravel extraction.

Minor Area M-3

Minor area M-3 is a sparsely settled area with a 1960 population of 123,900. The largest city in the minor area is Paris with a population of about 7,800. Average personal per capita income was $1,001, below the State average of $1,322. Urban population equaled 20 percent of the total population.

Agricultural employment accounted for 33.8 percent of total employment in 1960. The total area in farm land, increased by 14,000 acres over the 1954 total, was 1.6 million acres in 1959, 1,200 of which were irrigated. The total value of farm products sold increased $8.3 million over the 1954 total to $54 million in 1959. Field crops accounted for 55.3 percent of the 1959 total, livestock products for 43 percent.

Manufacturing has just begun to develop. By 1964, there were 15 establishments employing 100 workers or over located in minor area M-3, four more than in 1958. There were no establishments employing more than 500 workers. The most important industries are apparel, furniture and wood products, machinery (including electrical machinery), fabricated metals, and food processing. One thermal electrical generating plant is located at Paris with a generating capacity of 5.6 megawatts.

Crude oil extraction was the most important mining activity in 1960, production equaling 1.2 million barrels representing 5.8 percent of Kentucky's total production.

Minor Area M-4

Minor area M-4 is an economically depressed area. Population in this minor area was 168,100 in 1960 and Hazard was the largest city with a population of about 6,000. Average personal per capita income was $690 compared to $1,322 for the Commonwealth of Kentucky and $1,850 for the Nation. Urban population accounted for only 7.3 percent of total population. Those persons 25 years old or older who have finished four years of high school account for only 3 percent of the total population compared to 8.8 percent for Kentucky.

Mining is the most important employment category in the area and is primarily confined to coal and oil extraction. In 1960, the area produced 14.4 million tons of coal and 1.8 million barrels of crude oil, representing 21.5 percent and 8.3 percent respectively of total State production.

Agricultural employment equaled 4,100 in 1960, one-fourth the 1950 figure, and between 1954 and 1959, 270,000 acres were taken out of farm production. Even so, the total value of farm products sold has remained close to the 1959 total of $7.9 million. Seventy percent of this total was composed of field crops.

Manufacturing has not yet gained a significant footing in the area. In 1964, there was only one establishment that employed as many as 100 workers. Of the small plants in the area, the most important are furniture and wood products, apparel, food processing, and machinery (including electrical machinery). No thermal electrical generating plants are located in the area.

Projected Population and Industrial Activity

Population of the Licking-Kentucky-Salt subarea is projected to increase from 722,700 in 1960 to 851,000 by 1980 and 1,403,000 by 2020. The subarea contained 3.8 percent of the total Ohio River Basin population in 1960 and is expected to contain 4 percent by 2020.

Table 6 shows the 1960 population and projected population for the minor areas.

Agricultural output is expected to manifest a low but continuing growth. Whereas total output amounted to $500 million in 1960, it is expected to total $547 million by 1980 and $667 million by the year 2000.

Manufacturing output is expected to grow at a faster rate. In 1960, total output was $739 million and is projected to be $1,837 million by 1980 and $3,994 million by 2000.

Table 7 shows 1960 output, total employment and manufacturing employment. Projections to 1980, 2000, and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Licking, Kentucky and Salt River Basins, seven other counties lying outside subarea M have land area within the Licking River Basin, nine other counties have land area within the Kentucky River Basin and seven other counties have land area within the Salt River Basin. The counties are listed in Tables 8a, 8b and 8c for the respective river basins.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Licking River Basin

Present and Projected Water Use

There are 19 central water supply systems in the Licking River Basin, serving a population of 98,340. The average daily water use is 84 gallons per capita.

In the basin, practically all of the water used is for municipal supplies and is from surface sources. The present municipal and industrial water use in the basin is shown in Table 9a. The boundary of minor area M-3 generally outlines the basin and within this minor area the principal water using communities are Paris, Cynthiana and Mount Sterling, accounting for 67 percent of the total water use in the minor area and 40 percent of the water use in the entire basin. Winchester obtains its water supply from the Kentucky River. The other major central supply is located in the Cincinnati S.M.S.A., in Kenton County, withdrawing water from the portion of the Licking River in Pool from Markland Dam on the Ohio River and furnishing water to a number of communities in this northern Kentucky county. This supply alone accounts for 37 percent of the water use in the basin.

Based on population increase and projected industrial activity, it is estimated that total water use will increase in the Licking River Basin as shown in Table 10a. It is estimated that total water use in the basin will increase over fivefold by 2020, with the major increase in minor area M-3 at about 6.5 times the 1960 amount.

Water Supply Problems

The projected total water supply figures shown in Table 10a, the 1 day in 30 years low flow data given in Table 5, and the availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11a are problem areas with the approximate time of onset of the problem.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11a

LICKING RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Flemingsburg	M-3	X			
Mount Sterling	M-3		X		
Morehead	M-3		X		
Paris	M-3	X			
Cynthiana	M-3	X			

In minor area M-3, the total water use is projected to increase to 8.6 mgd by 1980, to 15.6 mgd by 2000, and to 31.5 mgd by 2020. Approximately 97 percent of the projected water use in the minor area will be for municipal use. The community of Mount Sterling, at present using local impoundments, during periods of high water usage is experiencing supply difficulties. This community should be planning now to increase their sources of supply. In the absence of dependable sources of ground water, it appears that continued use of surface water is indicated. Alternate solutions to this problem are either development of additional local impoundments, development of a source of supply in a large stream capable of meeting projected needs, or allocation of water supply storage in Federal reservoirs either in the Licking or Kentucky River Basin. Flemingsburg for the past several years has experienced acute shortages of water during the summer months, and Morehead by 1980 will probably need additional water supply. In the absence of a dependable source of ground water, reliance must continue primary on surface sources. Development of additional local impoundments could be one solution, but the permanent long range solution would probably be to develop a source in the Licking River where a dependable supply of water exists. Morehead could possibly meet its future needs by a reallocation of storage in Cave Run Reservoir.

Paris on Stoner Creek and Cynthiana on the South Fork of the Licking River apparently have a sufficient quantity of supply although problems with taste and odor will continue and require intensified efforts to produce water of acceptable quality. Off-stream storage of water during periods of higher flows or allocation of storage of good quality water in Federal reservoirs are alternate solutions to this problem.

Undoubtedly there are other smaller communities which will have water supply problems, but it is beyond the scope of this report to define these problem areas.

Kentucky River Basin

Present and Projected Water Use

There are 46 central water supply systems in the Kentucky River Basin, serving a population of 293,945. Average daily water use in the basin is 92 gallons per capita.

In the basin, practically all of the water used is for municipal supplies and about 89 percent of the water comes from surface sources. The present municipal and industrial water use in the basin is shown in Table 9b. The boundaries of minor areas M-2 and M-4 generally outline the basin, and within these minor areas the major water using communities are Lexington, Frankfort, Danville, and Winchester. These four communities, using surface water, account for nearly 70 percent of the total water used in the basin for municipal supplies. Withdrawal of water by Winchester from the Kentucky River constitutes a transbasin diversion as the community is located on the divide between the Licking River Basin and the Kentucky River Basin and discharges wastes to the Licking River Basin. Transbasin diversions also occur at Eminence, Lawrenceburg and Harrodsburg. These communities draw water supplies from the Kentucky River Basin and discharge wastes to the Salt River Basin. The city of Carrollton, which is the major ground water user, obtains its water from the alluvium along the Kentucky River near its confluence with the Ohio River and is not actually dependent on the water resources of the basin for its supply. The self-supplied industrial water use in the basin is small but considerable water is supplied for commercial and light industrial use in the Lexington area, but this is principally supplied from the municipal system.

Based on population increase and projected industrial activity, it is estimated that total water use in the Kentucky River Basin will increase as shown in Table 10b. It is estimated that total water use in the basin will increase more than 5.5 times by 2020, with the major increases being in the lower basin areas in the Lexington S.M.S.A. where future needs will amount to about 6 times the 1960 use.

Water Supply Problems

The projected total water supply figures shown in Table 10b, the 1 day in 30 years low flow data given in Table 5, and the avail-

ability of ground water as reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11b are problem areas with the approximate time of onset of the problem.

TABLE 11b

KENTUCKY RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Lexington	M-2	X			
Georgetown	M-2	X			
Hazard	M-4	X			
Jackson	M-4	X			
Richmond	M-4		X		

In the portion of minor area M-1 within the Kentucky River Basin, the total water use is projected to increase to over 7 mgd by the year 1980, to over 13 mgd by 2000, and to over 30 mgd by 2020. Approximately 75 percent of the projected water use in this portion of minor area M-1 will be for municipal use. With the exception of the city of Danville, which obtains its water supply from the Dix River, all of the major communities in this area obtain their supplies from the main stem of the Kentucky River. Flow in the river should be sufficient to meet their needs throughout the study period. The low flow of the Dix River might not be sufficient to meet the future needs of the city of Danville, but since they have the storage pool of Herrington Lake to draw from, it is very unlikely that they will have water supply problems either.

In minor area M-2, comprising the major portion of the lower Kentucky River Basin, the total water use is projected to increase to over 32 mgd by the year 1980, to about 58 mgd by 2000, and to over 128 mgd by 2020. Approximately 90 percent of the projected water use

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

in this minor area will be for municipal use. The city of Lexington, the major water user in this area, presently uses the Kentucky River as its principal source of supply augmented by local impoundments. If it were not for the storage provided by the lock and dam system on the river, this city would probably have water supply problems at present withdrawal levels during a drought period. In the absence of dependable sources of ground water, it appears that continued use of surface water is indicated. Solutions to this problem are limited due to the cost of land acquisition in the local area and the poor topography for dam construction. It appears that the best solution for Lexington would be to purchase water supply storage in the Federal reservoirs being proposed in the Kentucky River Basin upstream of the city's intake. In the Georgetown area, water supplies have been developed from ground sources but the firm yield of available ground water is being utilized and it appears that new sources of supply must be developed in the near future if the system is to expand to serve growing suburban areas. In the absence of other dependable ground sources, reliance must be placed on surface sources. There are several possible alternatives--local impoundments, storage in Federal reservoirs, and tie-in with the municipal system of the city of Lexington. Because of the geographical location of the Kentucky River, Georgetown, and Lexington, it appears that this third solution may be the most feasible and economical.

As a result of past water supply problems, the city of Winchester has gone to the Kentucky River for its water and has created a transbasin diversion. The Kentucky River will provide an adequate source of supply for Winchester in the foreseeable future.

In minor area M-4, the upper Kentucky Basin area, the total water use is projected to increase to 3.5 mgd in 1980, to 5 mgd in 2000, and to 9 mgd by 2020. Some 70 percent of the projected future water use in this area is for municipal supplies. The communities of Hazard and Jackson on the North Fork of the Kentucky River use this stream as their source of supply. Both communities have experienced periods of shortage in water supply during periods of low flow and will have them again in the near future if supplemental storage is not developed. The alternatives appear to be development of either upland storage or greater storage in the river. The city of Richmond at present has several local impoundments in the Otter Creek area and is now using some 95 percent of their estimated safe draft so it is apparent that additional sources of supply for this area will have to be developed in the near future. Ground water is

not dependable in this area and so alternatives are limited to additional local impoundments or construction of an intake on the Kentucky River. In the long run, it appears that location of an intake on the Kentucky River would provide the best solution as adequate natural flow appears to be available in the river.

Undoubtedly, there are other smaller communities which will have water supply problems, but it is beyond the scope of this report to define these problem areas.

Salt River Basin

Present and Projected Water Use

As shown in Table 9c, there are 18 central water supply systems in the Salt River Basin serving a population in 1960 of 38,845. The average daily water use is 71 gallons per capita.

In this basin, the industrial demand, primarily for the distilling industries, is nearly as great as the municipal demand. Practically all water for both industrial and municipal systems is obtained from surface sources. The present municipal and industrial uses from basin sources are shown in Table 9c. It should be noted that in the northern area of the basin there is a growing amount of transbasin diversion into the basin from the Ohio River through extensions of the Louisville water system into suburban areas located in Salt River. Return of the waste water from this use results in more dependable but degraded low flows in Floyds Fork. The boundaries of minor area M-1 generally outline the basin and, within this minor area, the principal water using communities are Shelbyville, Bardstown, Springfield, and Lebanon, accounting for 85 percent of the municipal water use in the minor area and 65 percent of the municipal water use in the basin. The other two major water users for this basin are the communities of Rogersville in Hardin County and LaGrange in Oldham County. These two supplies account for another 15 percent of the municipal water use in the basin. Approximately 87 percent of the industrial water use in the basin is by the distilling industry in Nelson County around Bardstown. Most of this supply comes from local impoundments. Other than the distilleries, there are no heavy water using industries in the basin area.

Based on the population increase and projected industrial activity, it is estimated that total water use will increase in the Salt River Basin as shown in Table 10c. It is estimated that water use in the total basin will increase over fivefold by 2020. The increase appears to be fairly well distributed throughout the basin.

Water Supply Problems

The projected total water supply figures shown in Table 10c, the 1 day in 30 years low flow data given in Table 5, and the availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11c are problem areas with approximate time of onset of the problem.

TABLE 11c

SALT RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Springfield	M-1			X	
Lebanon	M-1		X		

In the Salt River Basin, the total water use is projected to increase to 7.5 mgd by the year 1980, to 13 mgd by 2000, and to 26 mgd by 2020. Approximately 63 percent of the projected water use is for municipal systems in the basin. In minor area M-1, the city of Springfield is presently dependent on local impoundments for its supply. The projected increase in water use in this area indicates that the city should develop additional water sources by the year 2000. Because of the distance of the city from proposed Federal reservoirs and the lack of dependable ground water sources in the area, it appears that the most feasible source of additional supply for this city will be additional development of local impoundments. The city of Lebanon in Marion County has also depended in the past on local impoundments for its source of supply, and it appears that their present source will not be dependable during an extended drought by the year 1980. Ground water is not a dependable source

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

in this area, so the alternatives for additional supply appear to be construction of additional local impoundments or purchase of storage in proposed Federal reservoirs in the basin. Decision as to which of these alternatives is more feasible will depend on a detailed cost study.

There are undoubtedly other smaller communities which will have water supply problems, but it is beyond the scope of this report to define these problem areas.

In addition to the future needs for water supply for municipal purposes, there will be a continually increasing need for additional water supply for the distilling industry for cooling water in times of low flow in the streams. Possible solutions to this problem are: industries can connect to municipal systems as some have already done for emergency or supplemental supplies, or new sources can be developed. In the long run, it will be necessary to look for new supplies as the growing demands on the municipal systems will eliminate the surplus water now being provided to industry. Since the dependable supplies in this basin must be developed from surface sources, it might be a good plan for the municipalities and the industries in the basin to combine their efforts in the development of new sources of supply.

VI WATER QUALITY CONTROL

Licking River Basin

Present and Projected Waste Loads

Present organic waste loads generated are shown in Table 12a. In the basin, over 80 percent of the waste loads generated are due to municipal sources, with over 65 percent located in the South Fork drainage area. A major water source is from Winchester discharging to Strodes Creek in the headwater of the South Fork of the Licking River. Other large waste loads in the basin discharged to tributaries of the South Fork are from Paris into Stoner Creek, Mount Sterling into Hinkston Creek, Cynthiana and Falmouth into the South Fork.

Other discharges occur at Morehead into Triplett Creek and at Elsmere in the lower portion of the basin, discharging to Banklick Creek. The majority of the wastes in the lower basin are collected, transported, treated and discharged to the Ohio River at Bromley, Kentucky.

Shown in Table 13a are the base and projected waste loads generated for the basin listed by minor areas. Organic waste loads generated are projected to increase fivefold by 2020 in the portion of minor area M-2 included in the Licking River Basin and 5.5 times in minor area M-3, while in the lower basin the increase is projected to only double the present waste loads by 2020 with most of the waste loads in this area diverted to the Ohio River after treatment.

Water Quality Control Problems

Listed in Table 14a are the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures for pollution control after secondary treatment or equivalent reduction of the organic waste loads.

The major problem in the reach of the Licking River in pool from Markland Dam on the Ohio River is primarily taste and odor caused by nutrients in the water promoting algal growths at lower flows. These nutrients are reaching the stream as residuals from secondary treatment plants upstream and from surface runoff. Although sanitary

TABLE 14a

LICKING RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Licking River-Main Stem	Newport	K-2	X			
Stoner Creek	Paris	M-3	X			
Strodes Creek	Winchester	M-2	X			
Hinkston Creek	Mount Sterling	M-2	X			
South Fork	Cynthiana	M-2	X			
Triplett Creek	Morehead	M-2	X			

wastes from communities located along the lower reach of the Licking River are collected, uncollectable wastes such as storm water overflows from combined sewers and street washings enter the stream along this reach. In order to assure a higher quality of water in this reach of stream, where the design flow is about 11 cfs, and to provide sufficient velocity for continued movement of residual wastes and uncollectable wastes, flows in the order of 60 cfs are needed at the present, increasing to 90 cfs by 1980, to 130 cfs by 2000, and to 175 cfs by 2020.

Another problem area is in the South Fork, where design low flow of less than 1 cfs at Cynthiana is not capable of assimilating residual waste loads discharged after secondary treatment. It is estimated that at the present, 30 cfs is needed, increasing to 40 cfs by 2020. Upstream in the headwater region, Winchester obtains its water supply from the Kentucky River Basin and discharges treated sewage effluent into Strodes Creek where design flow is negligible. It is estimated that total flows in the order of 12 cfs are needed at the present, increasing to 15 cfs by 1980, to 22 cfs by 2000, and to 40 cfs by 2020. Since Winchester is in the headwater region, sites are not available for storage of water for regulation of streamflow. Sewage plant effluent could be returned to the Kentucky River Basin but this would deny reuse of this water to downstream users in the Licking River Basin. Therefore, intensive treatment and holding ponds for "polishing" the effluent or the transbasin movement of water for dilution may be a solution to the problem.

Below Paris in Stoner Creek where design flow is about 0.5 cfs, needs at the present are 20 cfs, increasing to 22 cfs by 1980, 25 cfs by 2000, and 30 cfs by 2020.

Below Morehead on Triplett Creek, a tributary of the upper main stem of the Licking River, and Mount Sterling on Hinkston Creek, a tributary of the South Fork where design flows are negligible, flows in the order of 5 cfs are needed at the present, increasing to about 8 cfs by 1980, 10 cfs by 2000, and about 15 cfs by 2020.

There are undoubtedly other small tributaries adversely affected by discharge of residual wastes remaining after secondary treatment, but it is beyond the scope of this report to define all of them.

Other major quality problems are not found in the Licking River Basin. There are no major thermal power generating plants located in the basin nor is there any heavy industry producing inorganic pollution except in the lower portion of the basin at Newport, Kentucky. Although there are coal deposits in the upper reaches of the main stem, these have not been heavily worked and mine drainage has not been a problem.

Kentucky River Basin

Present and Projected Waste Loads

Present organic waste loads generated are shown in Table 12b. In the basin, slightly over 50 percent of the organic waste loads generated are due to municipal wastes. Minor area M-2, which includes the Lexington S.M.S.A., accounts for approximately 90 percent of the total industrial and municipal organic waste loads generated in the basin. Approximately 47 percent of the organic wastes generated in minor area M-2 are in Fayette County, where Lexington is the major city with the other major source being the municipal and industrial organic discharges in Franklin County from the area in and around Frankfort.

Shown in Table 13b are the base and projected waste loads generated for the basin listed by minor areas. Organic waste loads generated are projected to increase more than fivefold by 2020 in all minor areas of the basin with the exception of minor area M-4 comprising the headwater region where only slightly better than a twofold increase is projected. Throughout the period of study, the M-2 area is projected to contribute approximately 90 percent of the total organic wastes discharged into the basin, of which approximately 50 percent will probably originate in the Lexington S.M.S.A.

Water Quality Control Problems

Table 14b lists the base and projected water quality control problem areas after secondary treatment or equivalent waste reduction is applied.

TABLE 14b

KENTUCKY RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Elkhorn Creek, South Fork	Lexington	M-2	X			
Elkhorn Creek, North Fork	Georgetown	M-2	X			
Main Stem	Lexington	M-2	X			
North Fork	Hazard	M-4	X			
North Fork	Jackson	M-4	X			
Otter Creek	Richmond	M-2	X			
Eagle Creek	Owenton	M-2		X		
Clarks Run	Danville	M-1	X			
Silver Creek	Berea	M-2	X			
Glenn's Creek	Versailles	M-2	X			
Jessamine Creek	Wilmore	M-2	X			
Jessamine Creek	Nicholasville	M-2	X			
White Oak Creek	Lancaster	M-2	X			
Logan Creek	Stanford	M-2	X			

Major quality control problems exist in the Elkhorn Creek area and in some of the very small tributaries which receive treated municipal wastes from package plants. The problems on small tributary streams have not been evaluated in this study. In the Elkhorn Creek area, the city of Lexington discharges all of its treated wastes into the headwater of the South Fork of Elkhorn Creek and during periods of low flow the stream is apparently anaerobic in some reaches. Storage to provide streamflow regulation of the amount required is not available for this small stream and it appears that, even with intensive treatment, the low flows are too small to assimilate the residual wastes. Land area is probably not available and even if it were the cost of "polishing" treatment would be

prohibitive compared to an alternative solution of constructing an outfall sewer about 15 miles and discharging treated wastes to the Kentucky River. If this were done, it is estimated that to assure satisfactory conditions in the Kentucky River, where the design flow is about 33 cfs, and provide sufficient velocity for continued movement of residual wastes, summer flows in the order of 270 cfs are needed at present increasing to 410 cfs by 1980, 550 cfs by 2000, and 700 cfs by 2020. Provision of these flows from storage from reservoirs upstream will provide sufficient assimilative capacity for effluent from secondary treatment entering the main stem throughout the study period from other sources.

Georgetown is located on the North Fork of Elkhorn Creek where there has been no natural flow at many times. In order to assimilate residual wastes remaining after secondary treatment, it is estimated that 9 cfs is required at the present, increasing to 12 cfs by 1980, to 18 cfs by 2000, and to 25 cfs by 2020. Storage to supply these needs is probably not available above Georgetown and intensive treatment is indicated. Another alternative may be transmission of treated effluent to a larger body of water possibly in combination with Lexington.

In the North Fork area of the Kentucky River in the reach of the North Fork below Hazard and above Jackson, there are problems of organic pollution that have been noted, as well as problems of high sulfate and chloride concentrations from runoff from mine drainage and brine pits and from oil well operations. Flows in the order of 25 cfs will be needed by 2020 to assimilate residual wastes remaining after treatment. The release of water from reservoirs on the North Fork for the control of residual organics from Lexington will also control residual organics in this reach, but control of mineral pollutants at the source will have to be undertaken.

There are a number of tributaries where effluent from treatment plants constitute nearly all the flow in the stream during periods of low flow. In Otter Creek below Richmond, flows in the order of 12 cfs are required at the present, increasing to 15 cfs by 1980, to 24 cfs by 2000, and to 45 cfs by 2020. In Jessamine Creek below Nicholasville, flows in the order of 5 cfs are needed at the present increasing to 7 cfs by 1980, to 9 cfs by 2000, and to 16 cfs by 2020. Provision of these flows at Nicholasville will meet the needs at Wilmore downstream. In Glenns Creek below Versailles, flows in the order of 7 cfs are required at the present increasing to 11 cfs in 1980, to 15 cfs by 2000 and to 25 cfs by 2020. Owenton discharges

residual wastes into the Eagle Creek Basin and flows in the order of 4 cfs are needed by 1980 increasing to 8 cfs by 2020. Since all of these communities are in the headwater of the respective tributary drainage areas and sufficient storage for purpose of streamflow regulation does not appear to be available, intensive treatment is indicated. An alternate solution to the problem is transmission of residual wastes to a larger body of water, the Kentucky River.

In the Dix River subbasin, the communities of Danville, Stanford and Lancaster are located on small tributaries where summer flows are very small. In Clarks Run below Danville, flows in the order of 10 cfs are needed at the present, increasing to 14 cfs by 1980, to 22 cfs by 2000, and to 40 cfs by 2020. In White Oak Creek below Lancaster and Logan Creek below Stanford, flows in the order of 4 cfs are needed at the present, increasing to 6 cfs by 1980, to 9 cfs by 2000, and to about 12 cfs by 2020. Storage does not appear to be available in the tributary basins above these communities and intensive treatment appears to be indicated.

In Silver Creek below Berea where low flows are very small, flows in the order of 6 cfs are needed at the present, increasing to 8 cfs by 1980, to 11 cfs by 2000, and to 20 cfs by 2020. Since storage of water for purpose of streamflow regulation does not appear to be available above Berea, intensive treatment is indicated and holding or "polishing" ponds for release during periods of higher flows in the stream may be the solution.

There are undoubtedly other small tributaries adversely affected by discharge of residual wastes remaining after secondary treatment, but it is beyond the scope of this report to define all of them.

In addition to the specific location on the North Fork of the Kentucky River affected by mine drainage which was described previously, there are many tributary streams in the headwater region adversely affected by mine drainage due to the extensive coal mining operations in this area.

Another potential water quality problem is heat. Major sources of heat release to streams from thermal power generating plants in the basin are located near Winchester, Burgin and Tyrone. A plant with a capacity of 196 megawatts is located near Winchester and a plant with a capacity of 137.5 megawatts is located at Tyrone. Both use surface water from the Kentucky River as a source of cooling water. During periods of low flow these plants

are the cause of increased stream temperatures in localized stream reaches. Another thermal power generating plant is located at Burgin, Kentucky, with a capacity of 293 megawatts and using Herrington Lake as a source of cooling water and discharging spent cooling water into the Dix River below Dix Dam.

Salt River Basin

Present and Projected Waste Loads

Present organic waste loads generated in the Salt River Basin are shown in Table 12c. The basin is not densely populated and over 90 percent of the total organic wastes discharged to the streams results from industrial activity. The majority of these wastes are discharged into Beech Fork near Bardstown, Rolling Fork above New Haven, and into the main stem of the Salt River in the vicinity of Shepherdsville.

Shown in Table 13c are the base and projected waste loads generated for the basin listed by minor areas. Organic waste loads generated are projected to increase nearly eightfold in minor area M-1, and over fourfold in that portion of minor area M-2 included in the Salt River Basin, and in other areas in the basin outside of subarea M, primarily in the Floyds Fork area in Jefferson and Bullitt Counties due to the urban and suburban growth from the city of Louisville.

Water Quality Control Problems

Table 14c lists the base and projected water quality control problem areas after secondary treatment or equivalent waste reduction is applied.

In the Beech Fork area below the town of Bardstown, there is an existing problem resulting from the discharge of inadequately treated organic wastes by the city and the local distilleries. At the present time, the situation is aggravated by lack of adequate in-plant separation of wastes by the distilleries and inadequate treatment of wastes before disposal to the stream. Even with good plant housekeeping and secondary treatment or equivalent reduction of organic wastes it is estimated that to provide an acceptable quality of water in this stream which has a design flow of about 1 cfs, summer flows in the order of 26 cfs are needed at present, increasing to 43 cfs by 1980, 70 cfs by 2000, and 110 cfs by 2020.

TABLE 14c

SALT RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Main Stem	Harrodsburg	M-2	X			
Main Stem	Shepherdsville	M-2	X			
Hammonds Creek	Lawrenceburg	M-2	X			
Clear Creek	Shelbyville	M-2	X			
Hardin Creek	Lebanon	M-2	X			
Road Run Creek	Springfield	M-2	X			
Beech Fork	Bardstown	M-2	X			
Rolling Fork	New Haven	M-2	X			
Floyds Fork	Jeffersontown	N-2	X			

In the Rolling Fork area near New Haven, organic pollution creates adverse quality conditions during periods of low flow. Nearly all of the organic wastes are discharged by distilleries and improved housekeeping procedures and treatment of wastes before discharge are needed. Because of the poor low flow characteristics in the stream, it is estimated that in addition to secondary treatment or equivalent reduction of wastes, summertime flows in the order of 5 cfs are needed at present, 7 cfs by 1980, 11 cfs by 2000, and 17 cfs by 2020 to provide an acceptable quality of water in the stream and to provide sufficient velocity for continued movement of residual wastes.

In the Floyds Fork area, it is expected that growth of the city of Jeffersontown and vicinity will result in an organic pollution problem in Floyds Fork in the reach between miles 20 and 40 above the mouth due to the discharge of effluent from treatment plants.

To provide a good quality of water in the stream and sufficient velocity to assure continued movement of residual organics remaining after treatment and uncollectable wastes, it is estimated that summer flows of 8 cfs are needed at the present, 10 cfs by 1980, 12 cfs by 2000, and 15 cfs by 2020.

In the main stem of the Salt River near Shepherdsville, the discharge of inadequately treated organic wastes by the municipalities in the area and the distilling plants located in northern Nelson

County have created adverse quality conditions in the lower reach of the stream. Conditions are aggravated by the reduced velocities which result from slackwater conditions caused by a navigation dam in the Ohio River which ponds water nearly up to Shepherdsville. The design streamflow in this reach of stream is very low and in order to provide acceptable quality and continual movement of residual organics through the pool area, flows in the order of 26 cfs are needed at present, increasing to 74 cfs by 1980, to 150 cfs by 2000, and to 240 cfs by 2020.

In the upper portion of the basin, unsatisfactory conditions exist in the main stem below Harrodsburg. Summer low flows are very small and in order to maintain satisfactory stream conditions, flows in the order of 9 cfs are needed at the present, increasing to 11 cfs by 1980, to 16 cfs by 2000, and to 30 cfs by 2020.

Unsatisfactory stream conditions exist at the present in Hammonds Creek below Lawrenceburg, Clear Creek below Shelbyville, and Hardin Creek below Lebanon, and flows in the order of 6 cfs are needed at the present, increasing to 9 cfs by 1980, to 15 cfs by 2000, and to 28 cfs by 2020. In Road Run Creek below Springfield, flows in the order of 3 cfs are needed at the present, increasing to 5 cfs by 1980, to 8 cfs by 2000, and to 15 cfs by 2020. Since these communities are all in the headwater region of these streams, intensive treatment is indicated, combined with holding or "polishing" ponds for release during periods of higher flows.

Quality problems unrelated to organic wastes are not found in the Salt River Basin and are not expected to develop in the future.

TABLES

TABLE 1a

LICKING RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky	*	Bath	100.0
"		Boone	1.9
"	*	Bourbon	100.0
"		Bracken	44.1
"		Campbell	43.8
"	*	Clark	36.6
"		Elliott	3.6
"	*	Fleming	100.0
"	*	Grant	36.4
"	*	Harrison	100.0
"		Kenton	86.5
"		Lewis	8.0
"	*	Maggofin	95.9
"		Mason	61.6
"	*	Menifee	62.3
"	*	Montgomery	88.2
"	*	Morgan	89.9
"	*	Nicholas	100.0
"	*	Pendleton	91.4
"	*	Robertson	100.0
"	*	Rowan	94.0

*Counties considered in economic projections of Licking River Basin.

TABLE 1b

KENTUCKY RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky	*	Anderson	28.9
"		Bell	3.8
"		Boone	1.7
"	*	Boyle	39.8
"	*	Breathitt	100.0
"		Carroll	63.5
"	*	Clark	63.4
"	*	Clay	92.8
"	*	Estill	100.0
"	*	Fayette	100.0
"	*	Franklin	100.0
"		Gallatin	36.2
"	*	Garrard	100.0
"	*	Grant	63.6
"		Harlan	13.4
"	*	Henry	89.9 1/
"		Jackson	44.6
"	*	Jessamine	100.0
"	*	Knott	71.8
"		Knox	9.4
"	*	Lee	100.0
"	*	Leslie	100.0
"	*	Letcher	78.0
"	*	Lincoln	60.1
"	*	Madison	100.0
"	*	Menifee	37.7
"	*	Mercer	30.1
"	*	Montgomery	11.8
"	*	Owen	100.0
"	*	Owsley	100.0
"	*	Perry	100.0
"	*	Powell	100.0
"		Rockcastle	17.2
"	*	Scott	100.0
"	*	Shelby	13.6
"		Trimble	23.0 1/
"	*	Wolfe	100.0
"	*	Woodford	100.0

1/ Includes area draining to Little Kentucky River.
*Counties considered in economic projections of Kentucky River Basin.

TABLE 1c

SALT RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky	*	Anderson	71.1
"	*	Boyle	60.2
"		Bullitt	98.4
"		Casey	18.5
"		Hardin	25.5
"	*	Henry	5.8
"		Jefferson	31.3
"		Larue	35.4
"	*	Marion	100.0
"	*	Mercer	69.9
"	*	Nelson	100.0
"		Oldham	30.6
"	*	Shelby	86.4
"	*	Spencer	100.0
"	*	Washington	100.0

*Counties considered in economic projections of Salt River Basin.

TABLE 2a

LICKING RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Licking River	3,670	320	0
South Fork	950	90	51

TABLE 2b

KENTUCKY RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Kentucky River	6,940	259	0
Eagle Creek	500	87	11
Elkhorn Creek	440	85	52.2
Dix River	460	77	118.1
Red River	480	57	190.3
South Fork	736	75	254.8
Middle Fork	545	97	258.6
North Fork	1,305	168	258.6

TABLE 2c

SALT RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Salt River	2,890	125	0
Rolling Fork	1,470 1/	115	12
Beech Fork	776	125	29
Floyds Fork	262	65	24

1/ Includes Beech Fork.

TABLE 3a

LICKING RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Winchester	Clark	Kentucky	7,156	8,333	8,233	8,594	9,226	10,187
Paris	Bourbon	"	5,859	6,310	6,204	6,697	6,912	7,791
Cynthiana	Harrison	"	3,603	3,857	4,386	4,840	4,847	5,641
Mount Sterling	Montgomery	"	3,932	3,995	4,350	4,782	5,294	5,370
Morehead	Rowan	"	1,105	981	825	1,901	3,102	4,170
Falmouth	Pendleton	"	1,180	1,330	1,876	2,099	2,186	2,568

TABLE 3b

KENTUCKY RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Lexington	Fayette	Kentucky	35,099	41,534	45,736	49,304	55,534	62,810
Frankfort	Franklin	"	10,465	9,805	11,626	11,492	11,916	18,365
Richmond	Madison	"	5,340	5,622	6,495	7,335	10,268	12,168
Danville	Boyle	"	5,420	5,099	6,729	6,734	8,686	9,010
Georgetown	Scott	"	4,533	3,903	4,229	4,420	5,516	6,986
Hazard	Perry	"	537	4,348	7,021	7,397	6,985	5,958
Nicholasville	Jessamine	"	2,935	2,786	3,128	3,192	3,406	4,275
Berea	Madison	"	1,510	1,640	1,827	2,176	3,372	4,302
Versailles	Woodford	"	2,268	2,061	2,244	2,548	2,760	4,060
Lancaster	Garrard	"	1,507	2,166	1,630	1,999	2,402	3,021
Irvine	Estill	"	272	2,705	3,640	3,631	3,259	2,955
Wilmore	Jessamine	"	-	1,157	1,329	1,228	2,337	2,773

TABLE 3c

SALT RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Harrodsburg	Mercer	Kentucky	3,147	3,765	4,029	4,673	5,262	6,061
Lebanon	Marion	"	3,077	3,239	3,248	3,786	4,640	4,813
Bardstown	Nelson	"	2,126	1,717	1,767	3,152	4,154	4,798
Shelbyville	Shelby	"	3,412	3,760	4,033	4,392	4,403	4,525
Jeffersontown	Jefferson	"	345	350	614	899	1,246	3,431
Radcliff	Hardin	"	-	-	-	-	-	3,384
Lawrenceburg	Anderson	"	1,723	1,811	1,763	2,046	2,369	2,523

TABLE 4

LICKING-KENTUCKY-SALT RIVER BASINS

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Pool Area (acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Licking River Basin					
Campbell County	R	200			3,500
Falmouth Lake	R	200			
Williamstown Lake	R	305			
Cave Run 1/	F, A, R	8,270	443,700		83,900
Nicholas	R	150			
Kentucky River Basin					
Lexington (3)	W	175			
Beltz Lake	R	135			
Bullock Pen Lake	R	142			
Elmer Davis Lake	R	138			
Corinth	R, W	105			
Herrington	R, W, P	1,000			
Buckhorn	F, W, R	1,230	157,700		21,800
Carr Fork 1/	F, A, R	710	44,800		3,450
Jackson	R	150			
Salt River Basin					
Beaver Creek	R	165			3,500
Simpson	R, W	250		7,000	
Shelby	R, W	150			414
Guist Creek	R, W	325			

1/ Under Construction

F - Flood Control
A - Low Flow Regulation
R - Recreation
W - Water Supply
P - Hydroelectric Power

TABLE 5

LICKING--KENTUCKY--SALT RIVER BASINS

Flow Data[3/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Licking River						
Farmers, Kentucky	831	1,076	0.7	24,000	3.1	
McKinneysburg, Ky.	2,326	3,038	3.8	54,100		
Falmouth, Ky.	2,367					3.5
Catawba, Ky.	3,300	4,131	2.5	86,300	10	
South Fork						
Cynthiana, Ky.	621	751	0.3	35,300	0.7	
Kentucky River						
Winchester, Ky.	3,955	5,223	10(est.)	92,400	33	
Richmond, Ky.[1/]	3,953					19
Frankfort, Ky.[2/]	5,412	7,023		115,000	112	27
Lockport, Ky.	6,180	8,247		123,000	163	
Dix River						
Danville, Ky.	318					
Middle Fork						
Tallega, Ky.	537	700	0.1	52,700		
South Fork						
Booneville, Ky.	722	1,028	0	66,100		
North Fork						
Hazard, Ky.	466				1.5	0.4
Jackson, Ky.	1,101	1,293	0	53,500	2.2	
Elkhorn Creek						
Frankfort, Ky.	473	599	0	22,400		
Salt River						
Shepherdsville, Ky.	1,197	1,533	0	57,700		
Beech Fork						
Bardstown, Ky.	669	890	0	27,900	0.9	
Rolling Fork						
Boston, Ky.	1,299	1,720	0.4	41,300	1.3	0.3

1/ Low flow regulated by Buckhorn Reservoir since 1960.
2/ Low flow regulated by Herrington Lake since 1925 and Buckhorn Reservoir since 1960.
3/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

TABLE 6

LICKING-KENTUCKY-SALT RIVER BASINS

Economic Subarea M
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation M-1									
Kentucky	Anderson	8,600	2,500						
"	Boyle	21,300	9,000						
"	Marion	16,900	4,800						
"	Mercer	14,600	6,100						
"	Nelson	22,200	4,800						
"	Shelby	18,500	4,500						
"	Spencer	5,700	0						
"	Washington	11,200	0						
	Subtotal	119,000	31,700	154,700		209,000		281,000	
Area Designation M-2									
Kentucky	Clark	21,100	10,200						
"	Fayette	131,900	111,900						
"	Franklin	29,400	18,400						
"	Garrard	9,700	3,000						
"	Grant	9,500	0						
"	Henry	11,000	0						
"	Jessamine	13,600	7,000						
"	Lincoln	16,500	0						
"	Madison	33,500	16,500						
"	Owen	8,200	0						
"	Scott	15,400	7,000						
"	Woodford	11,900	4,100						
	Subtotal	311,700	178,100	385,000		507,000		687,000	
Area Designation M-3									
Kentucky	Bath	9,100	0						
"	Bourbon	18,200	7,800						
"	Fleming	10,900	0						
"	Harrison	13,700	5,600						
"	Maggoffin	11,200	0						
"	Menifee	4,300	0						
"	Montgomery	13,500	5,400						
"	Morgan	11,100	0						
"	Nicholas	6,700	0						
"	Pendleton	10,000	2,600						
"	Robertson	2,400	0						
"	Rowan	12,800	4,200						
	Subtotal	123,900	25,600	184,500		249,000		298,000	
Area Designation M-4									
Kentucky	Breathitt	15,500	0						
"	Clay	20,700	0						
"	Estill	12,500	3,000						
"	Knott	17,400	0						
"	Lee	7,400	0						
"	Leslie	10,900	0						
"	Letcher	30,100	3,200						
"	Owsley	5,400	0						
"	Perry	35,000	6,000						
"	Powell	6,700	0						
"	Wolfe	6,500	0						
	Subtotal	168,100	12,200	126,800		131,000		137,000	
Total Subarea M		722,700	247,600	851,000	301,000	1,096,000	470,000	1,403,000	915,000

TABLE 7

LICKING-KENTUCKY-SALT RIVER BASINS

Economic Subarea M
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation M-1													
Kentucky	Anderson	3,100	670										
"	Boyle	7,200	1,210										
"	Marion	5,300	1,000										
"	Mercer	5,300	1,010										
"	Nelson	6,300	1,790										
"	Shelby	6,900	780										
"	Spencer	2,200	300										
"	Washington	3,500	630										
	Subtotal	39,800	7,390	175.8	134	166	246	194	257	558	284	390	1241
Area Designation M-2													
Kentucky	Clark	7,700	1,460										
"	Fayette	49,800	7,540										
"	Franklin	11,700	2,510										
"	Garrard	3,800	600										
"	Grant	3,400	500										
"	Henry	3,700	340										
"	Jessamine	5,100	550										
"	Lincoln	4,800	880										
"	Madison	11,900	1,510										
"	Owen	2,900	190										
"	Scott	6,000	1,110										
"	Woodford	4,500	930										
	Subtotal	115,300	18,120	411.7	122	165	239	163	230	507	224	317	1032
Area Designation M-3													
Kentucky	Bath	2,800	370										
"	Bourbon	6,700	1,140										
"	Fleming	3,500	350										
"	Harrison	5,100	1,000										
"	Maggofin	1,700	130										
"	Menifee	1,100	140										
"	Montgomery	4,400	490										
"	Morgan	2,700	160										
"	Nicholas	2,400	410										
"	Pendleton	3,500	770										
"	Robertson	700	20										
"	Rowan	3,400	680										
	Subtotal	38,000	5,660	107.8	159	217	292	228	383	650	335	622	1478
Area Designation M-4													
Kentucky	Breathitt	2,500	210										
"	Clay	3,800	280										
"	Estill	3,300	600										
"	Knott	2,700	150										
"	Lee	1,500	120										
"	Leslie	1,700	180										
"	Letcher	6,100	200										
"	Owsley	1,100	20										
"	Perry	6,800	310										
"	Powell	1,600	370										
"	Wolfe	1,400	60										
	Subtotal	32,500	2,500	44.4	97	141	229	133	194	502	185	300	946
Total Subarea M		225,600	33,670	739.7	127	172	249	176	259	540	248	384	1142

*In millions of 1960 dollars.
**1960 = 100

TABLE 8a

LICKING RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Boone	K-2	Ohio-Cincinnati
"	Bracken	K-3	Ohio-Cincinnati
"	Campbell	K-2	Ohio-Cincinnati
"	Elliott	J-1	Guyandot-Big Sandy-Little Sandy
"	Kenton	K-2	Ohio-Cincinnati
"	Lewis	H-1	Ohio-Huntington
"	Mason	K-3	Ohio-Cincinnati

TABLE 8b

KENTUCKY RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Bell	S-5	Cumberland
"	Boone	K-2	Ohio-Cincinnati
"	Carroll	N-3	Ohio-Louisville
"	Gallatin	K-1	Ohio-Cincinnati
"	Harlan	S-5	Cumberland
"	Jackson	S-5	Cumberland
"	Knox	S-5	Cumberland
"	Rockcastle	S-5	Cumberland
"	Trimble	N-3	Ohio-Louisville

TABLE 8c

SALT RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Bullitt	N-2	Ohio-Louisville
"	Casey	P-3	Green
"	Hardin	P-2	Green
"	Jefferson	N-2	Ohio-Louisville
"	Larue	P-2	Green
"	Oldham	N-2	Ohio-Louisville

TABLE 9a

LICKING RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation M-2											
Kentucky	Clark	0									0
"	Fayette	0									0
"	Franklin	0									0
"	Garrard	0									0
"	Grant	1	2,460		2,460	.125		.125	51	Grassey Creek, Impoundments	0
"	Henry	0									0
"	Jessamine	0									0
"	Lincoln	0									0
"	Madison	0									0
"	Owen	0									0
"	Scott	0									0
"	Woodford	0									0
	Subtotal	1	2,460	—	2,460	.125	—	.125	51		0
Area Designation M-3											
Kentucky	Bath	1	1,665		1,665	.090		.090	54	Slate Creek	0
"	Bourbon	3	11,390		11,390	1.701		1.701	149	Hinkston Creek, Stoner Creek	0
"	Fleming	1	2,220		2,220	.158		.158	71	Fleming Creek	0
"	Harrison	1	12,200		12,200	1.000		1.000	82	South Fork Licking River	0
"	Magoffin	1	925	925		.075	.075		81	Well	0
"	Menifee	0									0
"	Montgomery	2	6,140		6,140	.745		.745	122	Slate Creek, Impoundment	0
"	Morgan	1	3,500		3,500	.249		.249	71	Licking River	0
"	Nicholas	1	2,600		2,600	.185		.185	71	Breed Fork Creek, Impoundment	0
"	Pendleton	2	3,045		3,045	.350		.350	115	Licking River	0
"	Robertson	1	400		400	.025		.025	63	Blue Licks, Licking River	0
"	Rowan	1	4,170		4,170	.350		.350	84	Evans Branch Lake and Triplett Creek	0
	Subtotal	15	48,255	925	47,330	4.928	.075	4.853	102		0
Other Areas in Basin											
Kentucky	Boone	1	1,800		1,800	.100		.100	56	Lakes	0
"	Bracken	1	825		825	.050		.050	61	Lakes	0
"	Kenton	1	45,000		45,000	3.000		3.000	67	Licking River	0
	Subtotal	3	47,625	—	47,625	3.150	—	3.150	66		0
	TOTAL	19	98,340	925	97,415	8.203	.075	8.128	84		0

Note: For Area Designation M-1 see Kentucky River and Salt River Basins.
For Area Designation M-4 see Kentucky River Basin.

TABLE 9b

KENTUCKY RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Systems	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation M-1											
Kentucky	Anderson	1	3,500		3,500	.500		.500	143	Kentucky River	0
"	Boyle	2	20,815	815	20,000	2.335	.035	2.300	112	Dix River, Well	0
"	Marion	0									0
"	Mercer	1	8,500		8,500	.690		.690	81	Kentucky and Salt Rivers	1.0
"	Nelson	0									0
"	Shelby	0									0
"	Spencer	0									0
"	Washington	0									0
	Subtotal	4	32,815	815	32,000	3.525	.035	3.490	107		1.0
Area Designation M-2											
Kentucky	Clark	1	16,000		16,000	1.000		1.000	63	Kentucky River, Lakes	0
"	Fayette	2	120,150	150	120,000	13.151	.011	13.140	109	Kentucky River, Well	0.1
"	Franklin	1	25,420		25,420	2.200		2.200	87	Kentucky River	1.5
"	Garrard	1	3,865		3,865	.170		.170	44	Reservoirs	0
"	Grant	1	1,120		1,120	.050		.050	45	Lake	0
"	Henry	2	3,660		3,660	.215		.215	59	Drennon Creek, Impoundments	0
"	Jessamine	2	9,270		9,270*	.445		.445	48	Kentucky River, Wells	0.2
"	Lincoln	2	3,860		3,860	.239		.239	62	Lake, Springs	0
"	Madison	2	19,200		19,200	1.450		1.450	76	Lakes, Springs, Tributaries, Otter Crk.	0.1
"	Owen	1	2,800		2,800	.200		.200	71	Lakes	0
"	Scott	3	9,050	8,550	500	.725	.700	.025	80	Royal Spring, Eagle Creek, Buffalo Springs and N. Elkhorn Creek	0.1
"	Woodford	2	8,445	7,400	1,045*	.475	.400	.075	56	Lees Branch, Wells	0.1
	Subtotal	20	222,840	16,100	206,740	20.320	1.111	19.209	91		2.1
Area Designation M-4											
Kentucky	Breathitt	1	2,300		2,300	.135		.135	59	North Fork Kentucky River	0
"	Clay	1	2,140		2,140	.190		.190	89	Big Cheese Creek	0
"	Estill	1	3,700		3,700*	.250		.250	68	Kentucky Creek	0
"	Knott	0									0
"	Lee	1	800		800	.056		.056	70	Kentucky River	0
"	Leslie	0									0
"	Letcher	8	11,370	11,370		1.247	1.247		110	Reservoir, Springs, Mine, Wells	0
"	Owsley	0									0
"	Perry	8	12,190	3,740	8,450	.978	.346	.632	80	N.Fk.Kentucky R., Mines, Wells	0
"	Powell	1	1,200		1,200	.085		.085	71	Red River	0
"	Wolfe	0									0
	Subtotal	21	33,700	15,110	18,590	2.941	1.593	1.348	87		0
Other Areas in Basin											
Kentucky	Carroll	1	4,590	4,590		.300	.300		65	Wells	0
	Subtotal	1	4,590	4,590		.300	.300		65		0
	TOTAL	46	293,945	36,615	257,330	27.086	3.039	24.047	92		3.1

* Combined Supplies

For Area Designation M-3 see Licking River Basin.

TABLE 9c

SALT RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Systems	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation M-1											
Kentucky	Anderson	0									0
"	Boyle	0									0
"	Marion	2	5,255		5,255	.540		.540	103	N.Fk.Rolling Fk., Rolling Fk. River	.1
"	Mercer	0									0
"	Nelson	4	7,575		7,575	.689		.689	91	Rolling Fk.River, Salt River, Lakes	2.0
"	Shelby	3	7,950		7,950	.475		.475	60	Mary Bass Lake, Clear Creek Reservoir, Lakes	0.1
"	Spencer	1	1,190		1,190	.090		.090	76	Salt River	0
"	Washingto..	3	4,150	350	3,800	.300	.050	.250	72	Beech Fk.River Impoundment, Wells, Lake	0
	Subtotal	13	26,120	350	25,770	2.094	.050	2.044	80		2.2
Other Areas in Basin											
Kentucky	**Bullitt**	3	4,425		4,425	.293		.293	66	**Rolling Fk. River, Salt River**	0.1
"	**Hardin**	1	5,600		5,600	.240		.240	43	**Wells and Impoundments on Mill Crk.**	0
"	**Oldham**	1	2,700		2,700	.130		.130	48	**Lake**	0
	Subtotal	5	12,725		12,725	.663		.663	52		0.1
	TOTAL	18	38,845	350	38,495	2.757	.050	2.707	71		2.3

Note: For Area Designation M-2 and M-4 see Kentucky River Basin.
For Area Designation M-2 and M-3 see Licking River **Basin.**

TABLE 10a

LICKING RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation M-2												
From Central Supplies	2,460	51	.1	3,100	75	.2	5,000	90	.5	10,300	100	1.0
Industrial			0			.2			.4			.7
Subtotal			.1			.4			.9			1.7
Area Designation M-3												
From Central Supplies	48,255	102	4.9	73,800	112	8.3	121,000	125	15.1	221,000	138	30.5
Industrial			0			.3			.5			1.0
Subtotal			4.9			8.6			15.6			31.5
Other Areas in Basin												
From Central Supplies	47,625	66	3.2	59,500	84	5.0	71,000	95	6.7	81,000	105	8.5
Industrial			0			.3			.5			.7
Subtotal			3.2			5.3			7.2			9.2
Licking River Basin												
From Central Supplies Total	98,340	84	8.2	136,400	99	13.5	197,000	113	22.3	312,300	128	40.0
Industrial Total			0			.8			1.4			2.4
GRAND TOTAL			8.2			14.3			23.7			42.4

Note: For Area Designation M-1 see Kentucky River and Salt River Basins.
For Area Designation M-4 see Kentucky River Basin.

TABLE 10b

KENTUCKY RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation M-1												
From Central Supplies	32,815	107	3.5	43,600	118	5.1	72,000	130	9.4	148,000	150	22.2
Industrial			1.0			2.1			4.1			8.2
Subtotal			4.5			7.2			13.5			30.4
Area Designation M-2												
From Central Supplies	222,840	91	20.3	280,800	100	28.1	455,000	110	50.1	936,000	122	114.2
Industrial			2.1			4.2			7.7			14.2
Subtotal			22.4			32.3			57.8			128.4
Area Designation M-4												
From Central Supplies	33,700	87	2.9	26,000	96	2.5	30,000	107	3.2	53,000	118	6.3
Industrial			0			1.0			1.8			2.7
Subtotal			2.9			3.5			5.0			9.0
Other Areas in Basin												
From Central Supplies	4,590	65	.3	9,200	84	.8	13,000	95	1.2	19,000	105	2.0
Industrial			0			.4			.8			1.0
Subtotal			.3			1.2			2.0			3.0
Kentucky River Basin												
From Central Supplies Total	293,945	92	27.0	359,600	102	36.5	570,000	112	63.9	1,156,000	125	144.7
Industrial Total			3.1			7.7			14.4			26.1
GRAND TOTAL			30.1			44.2			78.3			170.8

- For Area Designation M-3 see Licking River Basin.

TABLE 10c

SALT RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation M-1												
From Central Supplies	26,120	80	2.1	34,700	92	3.2	58,000	101	5.9	120,000	112	13.4
Industrial			2.2			2.8			4.5			9.2
Subtotal			4.3			6.0			10.4			22.6
Other Areas in Basin												
From Central Supplies	12,725	52	0.7	17,500	74	1.3	23,000	91	2.1	26,500	100	2.7
Industrial			0.1			.2			.3			.5
Subtotal			0.8			1.5			2.4			3.2
Salt River Basin												
From Central Supplies Total	38,845	71	2.8	52,200	84	4.5	81,000	99	8.0	146,500	110	16.1
Industrial Total			2.3			3.0			4.8			9.7
GRAND TOTAL			5.1			7.5			12.8			25.8

Note: For Area Designation M-2 and M-4 see Kentucky River Basin.
For Area Designation M-2 and M-3 see Licking River Basin.

TABLE 12a

LICKING RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation M-2						
Kentucky	Clark	1	10,185	Strodes Creek	10,185	3,200
"	Fayette	0	0		0	0
"	Franklin	0	0		0	0
"	Garrard	0	0		0	0
"	Grant	1	1,610	Goose Creek	1,610	2,500
"	Henry	0	0		0	0
"	Jessamine	0	0		0	0
"	Lincoln	0	0		0	0
"	Madison	0	0		0	0
"	Owen	0	0		0	0
"	Scott	0	0		0	0
"	Woodford	0	0		0	0
	Subtotal	2	11,795		11,795	5,700
Area Designation M-3						
Kentucky	Bath	1	1,040	Dry Branch	1,040	0
"	Bourbon	1	7,790	Stoner Creek	7,790	1,500
"	Fleming	1	2,065	*Town Branch to Fleming Creek*	2,065	500
"	Harrison	1	5,640	**S. Fk. Licking River**	5,640	2,200
"	Magoffin	1	1,175	Licking River	1,175	0
"	Menifee	0	0		0	0
"	Montgomery	1	5,370	Hinkston Creek	5,370	200
"	Morgan	1	1,165	Licking River	1,165	0
"	Nicholas	0	0		0	500
"	Pendleton	2	3,020	S.Fk.Licking River, Licking River	3,020	500
"	Robertson	0	0		0	0
"	Rowan	1	4,170	Triplett Creek	4,170	700
	Subtotal	10	31,435		31,435	6,100
Other Areas in Basin						
Kentucky	Kenton	1	4,605	Bullock Pen Crk. to Banklick Creek	4,605	0
	Subtotal	1	4,605		4,605	0
	TOTAL	13	47,835		47,835	11,800

Note: For Area Designation M-1 see Kentucky and Salt River Basins.
For Area Designation M-4 see Kentucky River Basin.

*NOT to be interpreted as waste loads to the stream.

TABLE 12b

KENTUCKY RIVER BASIN

Base Municipal and Industrial Organic Waste **Production**

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation M-1						
Kentucky	Anderson	0	0		0	0
"	Boyle	1	9,010	Clarks Run to Dix River	9,010	3,200
"	Marion	0	0		0	0
"	Mercer	0	0		0	0
"	Nelson	0	0		0	0
"	Shelby	0	0		0	0
"	Spencer	0	0		0	0
"	Washington	0	0		0	0
	Subtotal	1	9,010		9,010	3,200
Area Designation M-2						
Kentucky	Clark	0	0		0	0
"	Fayette	6	67,560	S.Elkhorn Crk.,W.Hickman Crk.	67,560	50,000
"	Franklin	1	18,355	Kentucky River	18,355	22,000
"	Garrard	1	3,020	White Oak Creek to Dix River	3,020	500
"	Henry	1	700	Town Creek to Drennon Creek	700	200
"	Jessamine	2	7,050	Town Fk.,Trib.of Jessamine Creek	7,050	1,000
"	Lincoln	1	2,020	St. Asaph Creek	2,020	800
"	Madison	2	16,470	Dreaming Creek, Brushy Fork	16,470	3,600
"	Owen	1	1,200	Stephens Creek, N.Severn Creek	1,200	300
"	Scott	1	6,985	North Fork Elkhorn Creek	6,985	17,000
"	Woodford	2	5,105	Glen Creek, Lees Branch	5,105	30,000
	Subtotal	18	128,465		128,465	125,400
Area Designation M-4						
Kentucky	Breathitt	1	1,850	North Fork Kentucky River	1,850	0
"	Clay	1	1,870	Goose Creek	1,870	0
"	Estill	1	3,875	Kentucky River	3,875	1,700
"	Knott	0	0		0	0
"	Lee	1	440	North Fork Kentucky River	440	0
"	Leslie	0	0		0	0
"	Letcher	2	2,540	N.Fk.Kentucky River, Boone Fork	2,540	600
"	Owsley	0	0		0	0
"	Perry	1	5,960	N.Fk.Kentucky River	5,960	300
"	Powell	0	0		0	0
"	Wolfe	0	0		0	0
	Subtotal	7	16,535		16,535	2,600
Other Areas in Basin						
Kentucky	Carroll	1	2,220	Kentucky River	2,220	1,700
	Subtotal	1	2,220		2,220	1,700
	TOTAL	27	156,230		156,230	132,900

Note: For Area Designation M-3 see Licking River Basin.

***NOT** to be interpreted as waste loads to the stream.*

TABLE 12c

SALT RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation M-1						
Kentucky	Anderson	1	2,525	Hammond Creek	2,525	200
"	Boyle	0	0		0	0
"	Marion	1	4,815	Hardins Creek	4,815	24,000
"	Mercer	1	6,060	Town Brook	6,060	1,700
"	Nelson	1	4,795	Town Branch, Rolling Fk., Cox Crk.	4,795	225,000
"	Shelby	1	4,525	Clear Creek	4,525	1,600
"	Spencer	1	935	Brashears Creek	935	0
"	Washington	1	2,380	Road Run Creek	2,380	1,200
	Subtotal	7	26,035		26,035	253,700
Area Designation M-2						
Kentucky	Clark	0	0		0	0
"	Fayette	0	0		0	0
"	Franklin	0	0		0	0
"	Garrard	0	0		0	0
"	Grant	0	0		0	0
"	Henry	1	1,960	Fox Run Creek	1,960	200
"	Jessamine	0	0		0	0
"	Lincoln	0	0		0	0
"	Madison	0	0		0	0
"	Owen	0	0		0	0
"	Scott	0	0		0	0
	Subtotal	1	1,960		1,960	200
Other Areas in Basin						
Kentucky	Bullitt	2	2,505	Salt River, Tanyard Branch, Long Lick Crk.	2,505	73,000
"	Jefferson	3	6,370	Chenoweth Run, Poke Lick Run, W. Br. Fern Creek	6,370	100
	Subtotal	5	8,875		8,875	73,100
	TOTAL	13	36,870		36,870	327,000

*NOT to be interpreted as waste loads to the stream.

TABLE 13a

LICKING RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation M-2				
Domestic and Commercial	11,795	14,900	24,100	49,500
Industrial	5,700	11,500	21,000	38,400
Subtotal	17,495	26,400	45,100	87,900
Area Designation M-3				
Domestic and Commercial	31,435	48,100	78,900	144,000
Industrial	6,100	15,500	30,900	64,000
Subtotal	37,535	63,600	109,800	208,000
Other Areas in Basin				
Domestic and Commercial	4,605	5,800	6,900	7,900
Industrial	0	0	400	700
Subtotal	4,605	5,800	7,300	8,600
Licking River Basin				
Domestic and Commercial Total	47,835	68,800	109,900	201,400
Industrial Total	11,800	27,000	52,300	103,100
GRAND TOTAL	59,635	95,800	162,200	304,500

*NOT to be interpreted as waste loads to the stream.

TABLE 13b

KENTUCKY RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation M-1				
Domestic and Commercial	9,010	12,000	19,800	40,600
Industrial	3,200	6,600	13,100	26,100
Subtotal	12,210	18,600	32,900	66,700
Area Designation M-2				
Domestic and Commercial	128,465	161,900	262,100	540,000
Industrial	125,400	253,300	461,500	845,000
Subtotal	253,865	415,200	723,600	1,385,000
Area Designation M-4				
Domestic and Commercial	16,535	12,700	14,600	26,000
Industrial	2,600	4,800	9,000	16,200
Subtotal	19,135	17,500	23,600	42,200
Other Areas in Basin				
Domestic and Commercial	2,220	4,400	6,300	9,300
Industrial	1,700	3,800	6,900	17,000
Subtotal	3,920	8,200	13,200	26,300
Kentucky River Basin				
Domestic and Commercial Total	156,230	191,000	302,800	615,900
Industrial Total	132,900	268,500	490,500	904,300
GRAND TOTAL	289,130	459,500	793,300	1,520,200

*NOT to be interpreted as waste loads to the stream.

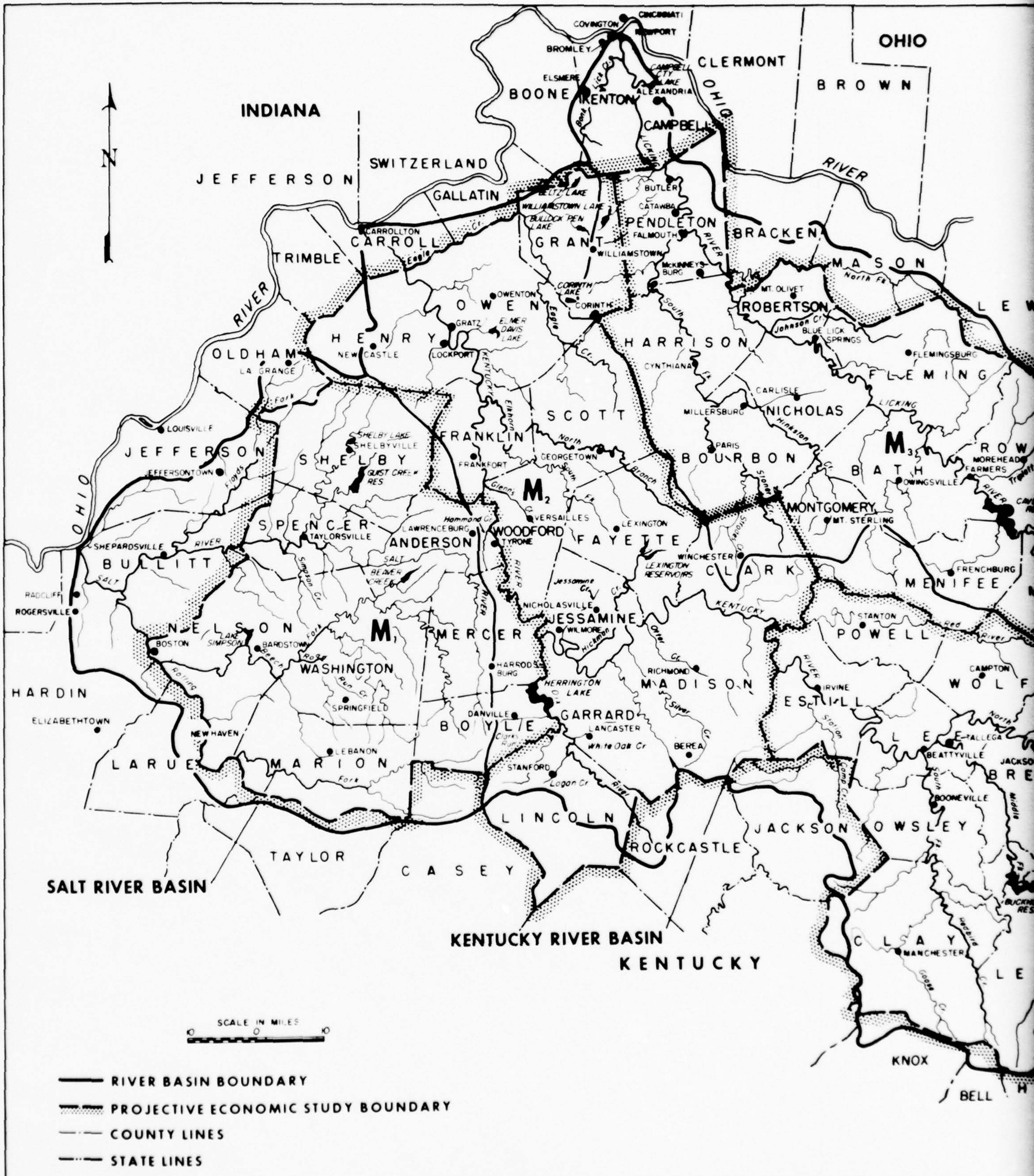
TABLE 13c

SALT RIVER BASIN

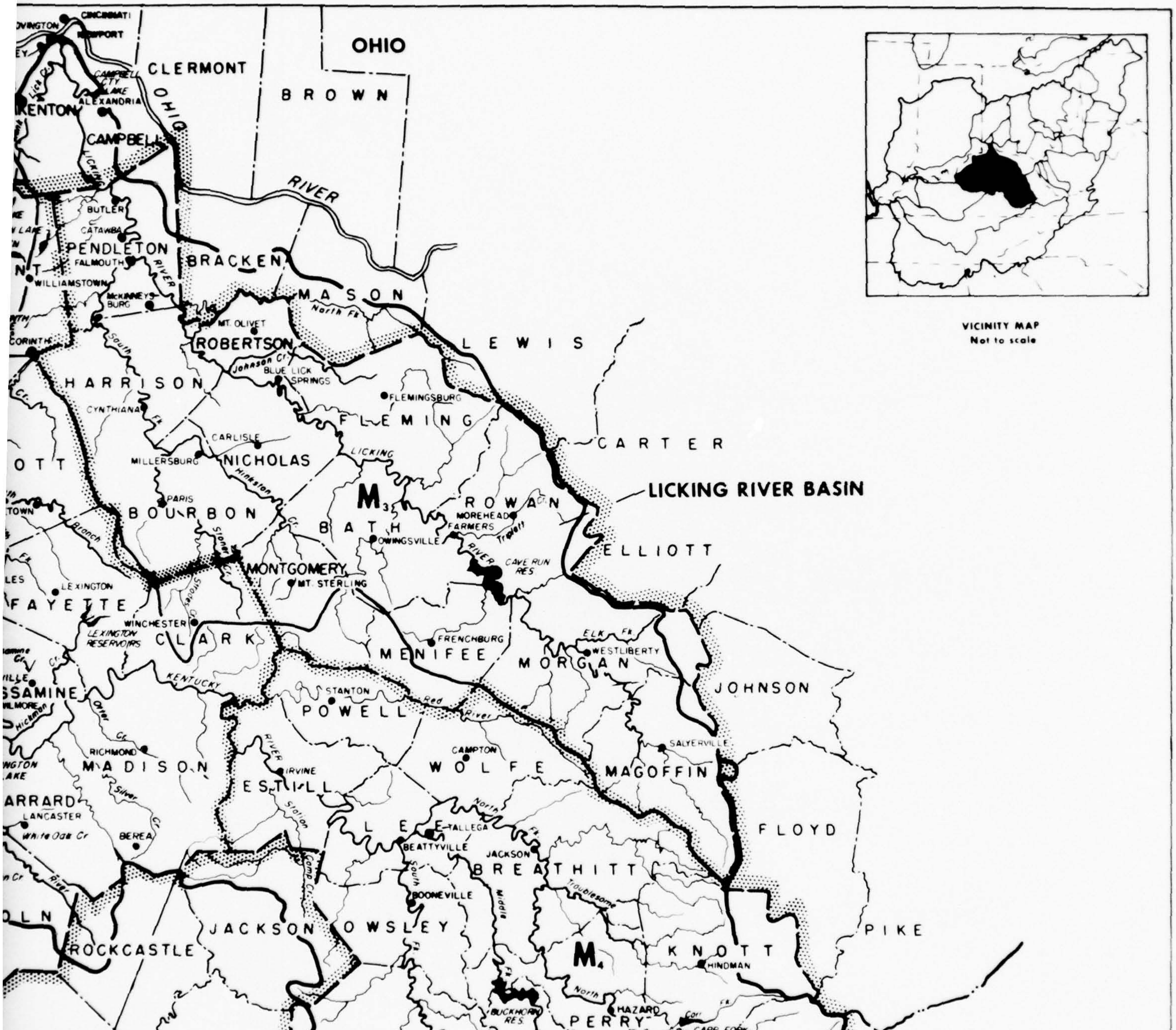
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation M-1				
Domestic and Commercial	26,035	34,600	57,300	117,000
Industrial	253,700	522,600	1,035,100	2,070,000
Subtotal	279,735	557,200	1,092,400	2,187,000
Area Designation M-2				
Domestic and Commercial	1,960	2,470	4,000	8,200
Industrial	200	400	700	1,300
Subtotal	2,160	2,870	4,700	9,500
Other Areas in Basin				
Domestic and Commercial	8,875	12,200	15,800	18,000
Industrial	73,100	136,000	232,500	396,000
Subtotal	81,975	148,200	248,300	414,000
Licking River Basin				
Domestic and Commercial Total	36,870	49,270	77,100	143,200
Industrial Total	327,000	659,000	1,268,300	2,467,300
GRAND TOTAL	363,870	708,270	1,345,400	2,610,500

*NOT to be interpreted as waste loads to the stream.



INDIANA
OHIO
CLERMONT
BROWN
SWITZERLAND
JEFFERSON
GALLATIN
BOONE
KENTON
CAMPBELL
CARROLL
TRIMBLE
GRANT
PENDLETON
BRACKEN
MASON
ROBERTSON
OWEN
HENRY
OLDHAM
HARRISON
FLEMING
NICHOLAS
SCOTT
FRANKLIN
SHELBY
JEFFERSON
BOURBON
BATH
MONTGOMERY
SPENCER
ANDERSON
WOODFORD
FAYETTE
BULLITT
CLARK
MENIFEE
NELSON
MERCER
JESSAMINE
POWELL
WASHINGTON
MADISON
ESTILL
WOLF
HARDIN
GARRARD
BOYLE
LEE
LARUE
MARION
LINCOLN
JACKSON
OWSLEY
ROCKCASTLE
TAYLOR
CASEY
CLAY
KNOX
BELL
M_1
M_2
M_3
OHIO RIVER
SALT RIVER BASIN
KENTUCKY RIVER BASIN
KENTUCKY
SCALE IN MILES
10 0 10
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STUDY BOUNDARY
COUNTY LINES
STATE LINES



OHIO RIVER BASIN FRAMEWORK STUDY

LICKING-KENTUCKY-SALT RIVER BASINS LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

9 67

FIGURE 9 1

GREEN RIVER BASIN

Subbasin Area
No. 10

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I SUMMARY

Municipal and Industrial Water Supply Problems

Generally, the flows in the lower section main stem of the Green River Basin are adequate to meet projected municipal and industrial water supply needs except that of cooling water for thermal electric plants in the lower Green River.

The headwater cities of the tributaries constitute the main water supply problems. Four of the seven largest cities in the basin, Madisonville, Russellville, Elizabethtown, and Franklin are located on or near the basin boundary. Flow records indicate that streams in the vicinity of these four cities frequently dry up during the summer. Reservoirs are used to provide water for three of the cities, Elizabethtown uses ground water. The expected M&I water use increase in these cities is in the order of four to six times the present use by 2020, indicating that new sources will be needed.

Water Quality Control Problems

Streamflows in Green River main stem are sufficient for quality control after secondary treatment since water quality storage is provided in Green River Reservoir. Further investigation is needed of heat pollution that may occur in the lower reaches of Green River from thermal electric plants.

Eighteen problems of water quality, nine of which are immediate, are enumerated in the report for various tributary reaches. Three of the eighteen of these may possibly be eliminated by a schedule of releases of seasonal storage in the Barren, Rough and Nolin Reservoirs. The others, which are on the tributaries, will need individual investigation to determine the most economical solution, and are of such magnitude that the Soil Conservation Service reservoirs could provide regulation, if flow regulation could be a purpose of such reservoirs.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Green River Basin is located in west central Kentucky and includes a small portion of northern Tennessee. It is bounded on the south and east by the Cumberland River Basin, on the west by the Tradewater and other minor Ohio River tributary watersheds, and on the north by the Kentucky and the Salt River Basins and other minor Ohio River tributary basins. The basin includes all or parts of 31 counties in Kentucky and parts of 3 counties in Tennessee. These counties are shown in Table 1 with the percentage of the land area that lies in the basin.

The headwaters of the Green River are in Lincoln and Casey Counties, Kentucky. The river flows 330 miles in a northwesterly direction to the Ohio River where it discharges about 8 miles above Evansville, Indiana, and 197 miles above the confluence of the Ohio with the Mississippi River (see Figure 10-1). The area drained by the Green River and its tributaries is about 9,273 square miles (377 of which are in northern Tennessee). The drainage areas and points of discharge of the main tributaries are shown in Table 2.

The existing navigation project on the Green and Barren Rivers provides for six locks and dams on the Green River and one on the Barren River. The project provides a navigable depth of 9 feet from the Ohio River to mile 103, Green River, and a navigable depth of 5.5 feet upstream. Locks and Dams No. 5 and 6 at river mile 168.1 and 181.7, Green River, respectively, were deactivated in 1951 and the pool formed by Dam 4 at mile 149 was drained by a breaching of the dam in May of 1965. The Louisville District Corps of Engineers has studied the navigation prospects and is currently recommending that operation and maintenance of the navigation project cease above mile 103 on the Green River. The existing pools above this point on the Green and Barren Rivers would be left unchanged but no lockages would be made.

Physical Features

The topography of the basin varies from the rugged hilly terrain in the eastern part of the basin, bordering the southern part of the Bluegrass region, to the deep valleys and cavern areas in the central section, and the swampy and wide alluvial plains of the western and northern sections. Elevations range from over 1,050 feet at the source of the river to the 337 foot pool elevation at the mouth of the river.

The underlying rock strata dip generally to the west and northwest. The basin consists of two physical land units, the Pennyroyal and the Western Coal Fields. The largest section, the Western Coal Fields, is in the western part of the watershed and the Pennyroyal is in the eastern part of the watershed. The sedimentary rock formation consists of limestones, cherty limestones, dolomites, sandstones, and shales. Subsurface drainage, which was developed in premodern times, has resulted in large solution caverns directly underlying the surface residual soils in the western portion of the Pennyroyal. Alluvial deposits in the valleys of the Western Coal Fields range up to 100 feet or more in depth and were probably laid down during the Wisconsin glacial epoch at a time when the Ohio River was draining the glacial occupied region.

Climate

The climate of the basin is the humid, temperate, continental type, and lies in the path of moisture-bearing storms which move from the Gulf region to the north Atlantic Coast. The mean annual temperature is about 57°F varying from a mean of 37°F in January to a mean of 76°F in July, allowing a growing season of approximately 180 days. The precipitation is fairly evenly distributed throughout the year with smaller amounts occuring during late summer and fall. The average annual precipitation varies from 42 inches in the lower portion of the basin to 49 inches in the upper portion with an average annual rainfall over the entire watershed area of about 47 inches.

Principal Communities and Industries

There are 23 cities with a population over 1,000, of which only three exceed 10,000. The largest city in the basin is Bowling Green on the Barren River. Table 3 lists the cities over 1,000 and illustrates the growth of these smaller communities.

The leading manufacturing industries are apparel, forest products and food. Although agriculture accounts for the major portion of the occupational activity in the basin, there are areas where mining of coal and rock asphalt and oil and gas production are important.

III WATER RESOURCES

Surface Water Resources

Quantity

Table 4 lists seven reservoirs in the Green River Basin totaling more than one hundred acres of surface area. The Green River Reservoir (under construction) has 64,500 acre-feet of storage for low flow regulation that provides for minimum releases of 150 cfs January through December. Nolin, Barren and Rough River Reservoirs have seasonal storage that provide varying amounts released September through November, depending on amount of inflow. Each of these reservoirs are controlled to release 75 cfs at top of conservation pool and 50 cfs until pool is depleted. There are six Soil Conservation Service reservoirs existing or programmed for the basin. In addition to the three with surface area over 100 acres listed in Table 4, Mud River #33, Caney Creek #2 and West Fork of Pond #8 are also programmed for the basin. These three have a total surface area of 150 acres and provide a total storage of 2,276 acre-feet, of which 183 are for water supply purposes.

Streamflow data shown in Table 5 were excerpted from data prepared by the Corps of Engineers.1/ Monthly mean flows vary widely throughout the year. The average annual flow at Livermore, Kentucky, for 32 years of record if 10,850 cfs. Flows at this station, which contains 82 percent of the basin drainage, vary from 19 percent of the average annual flow passing in February to .9 percent passing in October. In the period from July to October the monthly flows vary from 3.2 to .9 percent of the average annual flow. Sixty-one percent of the average annual runoff passes the Livermore gage from December 1 to April 1, 27 percent from April 1 to July 1, and 12 percent from July 1 to December 1.

Quality

U. S. Geological Survey data obtained from the Kentucky Water Pollution Control Commission indicate from essentially daily analysis of Green River water at Munfordville from 1953 to 1957, inclusive, that pH varied from 6.9 to 8, hardness as $CaCO_3$, to a

1/ Hydrology of Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

maximum value of 166 ppm, and dissolved solids to a maximum of 254 ppm of which sodium constituted 13 ppm. These values appeared in streamflows which varied from about 100 to 28,000 cubic feet per second. For the period October 1, 1950 to September 30, 1957 the average chloride content of the Green River at Munfordville was 3.9 ppm. Maximum water temperature has been 82°F.

In 1958 chloride concentrations began to rise in this area as oil field brine discharge into the river became apparent. The brines affected the Green River as far down as South Carrollton in Muhlenburg County. The discharges brought about an emergency situation which was attacked from all angles by State agencies and oil operators. Latest reports indicate that this situation has been corrected. Other oil field wastes and brines have been local in nature but have affected water quality in small streams tributary to the Green River and Rough River in the lower reaches.

The relatively high natural alkalinity of the normal stream waters tends to localize the effects to any mine drainage and it is only apparent in a few small tributaries, with no noticeable effect on the larger main streams.

The Barren River is widely used for recreational purposes in such ways as boating, fishing, and swimming. The fishing is considered to be excellent throughout the length of the river.

U. S. Geological Survey records of Pond River near Sacramento, Kentucky, a tributary which drains a strip-mine area, shows pH values of 3, hardness in excess of 800 ppm and dissolved solids in excess of 1,600 ppm of which sulfate, iron, and sodium are, respectively, 1,120, 14, and 58 ppm maximum values.

Ground Water Resources

Quantity

The U. S. Geological Survey[1/] describes the Green River as rising in Lincoln County in the Mississippian Plateau and flowing westward across Mississippian rocks to Butler County where it enters the area of Pennsylvanian rocks in the Western Coal Field region, and then flowing northwestward across these rocks to its junction with the Ohio River.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

Yields of high capacity wells in sandstones of the Pennsylvanian System range from 20 to 150 gpm. The depth of these wells range from 50 to 900 feet.

Limestone of the Mississippian System will yield 30-300 gpm from wells 200-650 feet deep. Springs in these rocks reportedly flow 100 to 1,500 gpm.

Deposits of alluvium are present along the Green River, but there are no large withdrawals of ground water from these deposits. Most known wells are shallow dug or driven type and supply only enough water for domestic use.

Ground water yields adequate for domestic, small municipalities and small industries needs are generally available throughout the region, particularly in areas underlain by sandstone in the Western Coal Field. Several communities in the basin are supplied entirely from wells or springs. Larger supplies would have to be provided for from surface impoundments.

Quality

No analyses of ground water are available, or are reported from the alluvium along the Green River; however, it is expected that quality would follow much the same as the Green River due to recharge induced by pumping of wells adjacent to the Green River.

The U. S. Geological Survey, Appendix E, reports the following ranges in the concentrations of common constituents in the ground water from the sandstone of the Pennsylvanian System:

Hardness	50 - 450 mg/l
Sulfate	25 - 250 mg/l
Chloride	5 - 75 mg/l
Total dissolved solids	200 - 2100 mg/l
Temperature	59°F

It is also reported that saline water becomes a problem in the limestone of the Mississippian age in some areas at depths greater than 75 feet.

IV THE ECONOMY

The Green subarea of the Projective Economic Study lies entirely within Kentucky and is nearly coextensive with the middle and upper drainage basins of the Green River. This area is predominantly agricultural in nature and includes the 19 counties listed in Tables 6 and 7 as shown on Figure 10-1, page 10-29. For the purpose of utilizing the projections of population and economic activity from the Projective Economic Study for estimating future water requirements and waste loads which are related to hydrology, the subarea has been divided into three minor areas designated P-1, P-2, and P-3. The P-1 area includes four counties in the western portion of the subarea, the P-2 area includes four counties in the northern portion of the subarea, and the P-3 area includes 11 counties in the southeastern portion of the subarea.

Economic Profiles

Minor Area P-1

P-1 is a rural area with a total population of 96,800, the most significant city being Russellville. The most inclusive measure of economic well-being, per capita personal income, shows the area to be below average with $1,157 in 1960 compared to $1,322 for Kentucky and $1,850 for the Nation.

Agriculture was the largest employment category in 1960, but had been declining at an average annual rate of 5.9 percent between 1950 and 1960. However, the value of farm products sold in 1959, $20 million, was an increase of three million dollars over the total value sold in 1954. Irrigation is not an important water use with only 240 acres irrigated in 1959.

Manufacturing is still in the development stage and characterized by many small establishments with only eight plants hiring more than 100 employees, the largest hiring over 500 workers. The major manufacturing industries are printing and allied products, furniture and wood products, machinery (including electrical machinery), and food processing.

This area is a major producer of crude petroleum and bituminous coal, extracting 1.2 million barrels of crude oil and 22 million tons of coal in 1960, which represented 4.7 and 32.8 percent respectively of total production in the State. In 1954, only 146,000 barrels crude oil were produced and 18 million tons of coal.

Minor Area P-2

The P-2 area had a population of 111,600 in 1960 with the most important city being Elizabethtown. This is a sparsely settled agricultural area with the urban population increasing from 5.9 percent of total population in 1950 to 14.3 percent in 1960.

Agriculture is the predominant employment category and accounted for 25 percent of total employment in 1960. Although employment has been declining, the total value of farm products sold in 1959, $20.4 million, revealed a $4.5 million increase in current output over 1954. Livestock and livestock products were the most important commodities sold in 1959. Less than 200 acres in the area are irrigated.

Manufacturing is an infant industry in the area with only four significant establishments in 1964, all within the 100-249 employment range. The major employment categories are machinery (including electrical machinery), apparel, food processing, and furniture and wood products.

The mineral industry is confined almost wholly to coal and crude oil extraction, producing 3.2 million tons and one million barrels respectively in 1960, which equaled 4.8 and 4 percent respectively of total State production. These figures represent an increase of 500,000 tons of coal and a decrease of 200,000 barrels of oil from the 1954 figures.

Minor Area P-3

This rural area had a 1960 population of 184,700 with only two significant cities, Glasgow and Bowling Green. The per capita personal income of $1,045 was considerably below the average of $1,322 for Kentucky and $1,850 for the Nation. The three eastern counties, Adair, Casey, and Green, lie within the designated Appalachian Region.

Agriculture is by far the most important employment category with 33 percent of total employment in 1960. Although employment has been decreasing at an average annual rate of 5.1, the value of farm products sold has been increasing. In 1959, the value of farm products sold amounted to $70 million representing an increase of $14 million in current output over 1954. Field crops and livestock and livestock products each accounted for approximately 50 percent of the total value. Irrigation is not an important water use with only 400 acres under irrigation in 1959.

Manufacturing is characterized by many small establishments although manifesting a strong growth rate. The number of plants above 100 employees doubled between 1958 and 1964 with 27 such plants existing in 1964. The major employment categories are apparel, food processing, machinery (including electrical machinery), and furniture and wood products.

Crude oil is of signal importance in mineral production in the area with five million barrels having been produced in 1960, the only other significant production being in crushed and broken stones. Total crude oil production amounted to 19.1 percent of the total State production. No crude oil was produced in the area in 1954 indicating the relatively new development of this mineral in the area.

Projected Population and Industrial Activity

Population is projected to increase from 393,100 in 1960 to 456,600 by 1980 and to 777,000 by 2020. The projected 1980 population represents the same share of Ohio River Basin projected population as did the 1960 population. (See Table 6).

Agricultural output is projected to increase from $323 million in 1960 to $508 million by 2010 in the Green subarea whereas, manufacturing output is expected to increase from $306 million in 1960 to $2.2 billion by 2010. (See Table 7).

In addition to the 19 counties included in the Green River Basin subarea in the Projective Economic Study, 15 other counties (12 in Kentucky and 3 in Tennessee) have land area in the basin. These counties are listed in Table 8.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

There are 43 central water supply systems in the Green River Basin serving 170,245 people. This population served is now using 15 million gallons daily (mgd) or an average of 89 gallons per capita daily. Additional self-supplied water use by industry is estimated to amount to 4 mgd or total water supply use of 19 mgd amounting to 116 gallons per capita daily use.

Table 9 summarizes the present municipal and industrial water use by economic area groupings and Table 10 shows the projected water use for these areas.

The 23 communities listed in Table 3 represent 88.3 percent of the population served from central supplies and 87.3 percent of the total water use at present in the Green River Basin. Five are now using ground water, representing 12.9 percent of the population served or about 11.4 percent of the water use in the basin. The other 18 communities use surface sources and represent 75 percent of the population served and 82.5 percent of the water used from central supplies in the basin.

Water Supply Problems

The projected total water supply figures shown in Table 10, the 1 day in 30 years low flow data given in Table 5, and availability of ground water reported by the U. S. Geological Survey[1] were utilized to make judgment as to need for future development of water supply source in various areas of the basin.

Four of the seven largest cities are located on or near the basin boundary. Two of these cities, Madisonville and Russellville, are in the minor area P-1, and Franklin is in minor area P-3. It is indicated that the order of magnitude of increase of municipal and industrial water supply will be about six by 2020 for minor area P-1 and P-3. While Elizabethtown is in a minor area indicated to have a

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

growth in the order of four by 2020, it could be expected that the majority of growth in that minor area would occur in Elizabethtown. Flow records indicate that streams in the vicinity of these four cities frequently dry up during the summer. Reservoirs provide water for three of the four cities, Elizabethtown uses ground water. When the growth projected occurs, it can be expected that these four cities will have a greater water supply problem due to their headwater location.

The other three larger cities are in relatively good position for future water supply. Bowling Green and Glasgow could be served from the new Barren Reservoir. Campbellsville, on Pitman Creek, could either enlarge its reservoir or be served by pipeline from the Green River Reservoir now under construction.

Table 11 lists the water supply problem areas of the basin and approximate time of onset of the problem.

TABLE 11

GREEN RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Madisonville	P-1		X		
Russellville	P-1	X			
Elizabethtown	P-2	X			
Franklin	P-3	X			

There are two steam electric plants in the Green River Basin for which water supply problems are anticipated. Green River Plant of 263.7 megawatt capacity and Paradise Plant of 1,354 megawatt capacity are located on the Green River at river mile 87 and 100 respectively from the mouth of the Green River.

Using the average figure of 1.2 cfs per megawatt capacity for once through cooling present flow requirements for two plants would be as follows:

Paradise	1,354	MW Capacity	-	1,630 cfs
Green River	263.7	MW Capacity	-	317 cfs

The one day in 30 year return natural low flow of the Green River at this point is 156 cfs. Based on this design figure the demand exceeds the supply by a factor of 10.

The average monthly flows at Livermore were examined for the period of record 1951 to 1960. It was found that for the 10 year period of record the average monthly flow fell below 1,630 cfs--25 months of the 120 months of record or 21 percent of the time flows were below that required for adequate cooling at Paradise. Twenty-one of the twenty-five months occurred during the months of August, September, October, and November and a frequency of at least one month in every year; therefore, cooling water needs at Paradise are an immediate problem that needs more detailed study.

Four existing reservoirs in the basin now fix low flows and assure that flows will be available for water supplies to minimize danger of failure. However, water supply storage is not provided for cooling and does not lessen the cooling water problem in the lower Green River.

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

There are 22 central sewage collection systems in the Green River Basin serving 112,550 people. Organic industrial wastes are estimated to contribute an additional 68,640 population equivalent in biochemical oxygen demand.

Table 12 summarizes the present pollutional loadings by economic minor areas and Table 13 shows the projected loads for these same areas.

Water Quality Control Problems

Each of the subareas shown were examined for relative distribution of the waste loads within the area and the assumption made that at least 85 percent of the loading could be removed by secondary waste treatment. The remaining waste loading was compared with the assimilative capacity of the 7 day average low flow with a return period of once in ten years as shown in Table 5.

If the projected waste loading exceeded that which would lower the dissolved oxygen in the stream below 4 parts per million at average summer temperature at the indicated 7 day average flow, the area was termed a potential problem to be further investigated in Type II Studies.

The water quality control problem areas foreseen in the Green River Basin are shown in Table 14 by tributary and vicinity along with approximate timing that the situation should occur.

If flow regulation is accepted as the most feasible method for alleviating the water quality problems shown, Bowling Green will require minimum flows in the stream in the order of 120 to 150 cfs by 2020 to assimilate wastes after adequate treatment. Glasgow, Campbellsville, Madisonville, and Russellville will require 40 to 60 cfs while flows in the order of magnitude of 15 to 25 cfs will assimilate adequately treated waste from Scottsville, Central City, Elizabethtown, Columbia, Greenville, and Franklin in the projected future.

The remaining seven problem areas will require from 7 to 15 cfs in the various stream sections to maintain quality control.

TABLE 14

GREEN RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity[1]	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Barren River-Main Stem	Bowling Green	P-3		X		
Barren River-Bays Fork	Scottsville	P-3	X			
Barren River-Scraggs & Beaver Crk.	Glasgow	P-3		X		
Barren River-Drakes Creek	Franklin	P-3		X		
Barren River-Drakes Creek	Portland[2]	S-3		X		
Barren River-Mill Creek	Tompkinsville	S-4		X		
Rough River-Main Stem	Hartford	P-2			X	
Rough River-Muddy Creek	Beaver Dam	P-2		X		
Pond River-Flat Creek	Madisonville	P-1	X			
Pond River-Cypress Creek	Central City	P-1	X			
Pond River-Caney Creek	Greenville	P-1	X			
Nolin River-Main Stem	Hodgenville	P-2			X	
Nolin River-Valley Creek	Elizabethtown	P-2	X			
Mud River-Town Branch	Russellville	P-1	X			
Bear Creek	Leitchfield	P-2	X			
Russell Creek	Columbia	P-3	X			
Pittman Creek	Campbellsville	P-3	X			
Green River-Main Stem	Liberty	P-3		X		

1/ Located in State of Kentucky unless otherwise noted.
2/ State of Tennessee.

Pollutional problems of the main stem Green River after secondary treatment or equivalent reduction of waste is provided for with permanent quality control storage in Green River Reservoir; however, the area above the reservoir has a potential problem at Liberty, Kentucky, as indicated in Table 14.

Supplemental flows from the Green River Reservoir provide a minimum 7 day average flow once in 10 years return frequency of about 350 cfs at the thermal power plant at Paradise, Kentucky.

It was stated in the water supply section that 1,630 cfs would be required for once through cooling to operate the plant at rated capacity. If this plant is operated at capacity and assuming a 13°F temperature rise for once through cooling, heat exchange problems would develop within the plant and at 1,200 cfs the temperature of the stream would approach 95°F during summertime operation.

The conclusion is drawn that heat is creating water quality problems in the lower Green River that can be solved by off-stream cooling.

The seasonal storage in Barren, Rough and Nolin Reservoirs should be further investigated for possibilities of firming up low flows to provide quality control minimum flow on the respective main stem rivers.

The quality problems shown in Table 14 that are on the smaller tributaries should be investigated as to possibilities of transporting the wastes to the larger streams for dilution, dilution of residual waste loads by storage in tributary reservoirs such as constructed by the Soil Conservation Service or other means that may present itself in more detailed studies.

TABLES

TABLE 1

GREEN RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky	*	Adair	92.3
"	*	Allen	100
"	*	Barren	100
"		Breckinridge	39.7
"	*	Butler	100
"	*	Casey	71.3
"		Christian	22.6
"		Cumberland	10.9
"		Daviess	71.2
"	*	Edmonson	100
"	*	Grayson	100
"	*	Green	100
"		Hancock	14.7
"	*	Hardin	56.3
"	*	Hart	100
"		Henderson	34.7
"	*	Hopkins	52.9
"	*	Larue	64.6
"		Lincoln	17.0
"	*	Logan	61.1
"		McLean	100
"	*	Metcalf	98.4
"		Monroe	68.5
"	*	Muhlenberg	100
"	*	Ohio	100
"		Russell	29.4
"	*	Simpson	77.3
"	*	Taylor	100
"		Todd	35.7
"	*	Warren	100
"		Webster	40.2
Tennessee		Clay	18.9
"		Macon	72.5
"		Sumner	70.9

*Counties considered in economic projections of Green River Basin.

TABLE 2

GREEN RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from confluence with Ohio River
Green River	9,273	370	0
Panther Creek	367	50	28.5
Pond River	756	89	55.0
Rough River	1,025	157	71.3
Mud River	430	60	108.6
Barren River	2,132	158	149.5
Bear Creek	200	40	168.5
Nolin River	750	122	183.5

TABLE 3

GREEN RIVER BASIN

Population of Principal Communities

City	County	State	1930	1940	1950	1960
Bowling Green	Warren	Kentucky	12,348	14,585	18,347	28,338
Madisonville	Hopkins	"	6,908	8,209	11,132	13,110
Glasgow	Barren	"	5,042	5,815	7,025	10,069
Elizabethtown	Hardin	"	2,590	3,667	5,807	9,641
Campbellsville	Taylor	"	1,923	2,488	3,477	6,966
Russellville	Logan	"	3,297	3,983	4,529	5,861
Franklin	Simpson	"	3,056	3,940	4,343	5,319
Central City	Muhlenberg	"	4,321	4,199	4,110	3,694
Scottsville	Allen	"	1,867	1,797	2,060	3,324
Greenville	Muhlenberg	"	2,451	2,347	2,661	2,198
Leitchfield	Grayson	"	950	1,146	1,312	2,982
Portland	Sumner	Tennessee	1,030	1,212	1,660	2,424
Greensburg	Green	Kentucky	770	1,176	1,032	2,334
Columbia	Adair	"	1,195	1,372	2,167	2,255
Tomkinsville	Monroe	"	850	1,438	1,859	2,091
Hodgenville	Larue	"				1,985
Horse Cave	Hart	"	1,259	1,278	1,545	1,780
Beaver Dam	Ohio	"	1,036	1,166	1,349	1,648
Hartford	Ohio	"		1,385	1,564	1,618
Liberty	Casey	"	549	676	1,291	1,578
Livermore	McLean	"	1,573	1,601	1,441	1,506
Cave City	Barren	"	773	960	1,119	1,418
Sebree	Webster	"	940	1,109	1,158	1,139

TABLE 4

GREEN RIVER BASIN

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Pool Area (acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Barren River	F, R	20,150	768,000		46,600
Green River	F, A, R	5,070	560,600		62,600
Nolin River	F, R	14,530	570,100		130,800
Rough River	F, R	10,260	314,200		99,800
*Mud River #51	F, R	826	5,036		13,944
*Mud River #2A	F, W, R	142	1,831	2,100	
*Valley Creek #4	F, W, R	162	1,110	920	680
Lake Malone	R	826			
Lake Peewee	W, R	300			
Shanty Hollow	R	107			

F - Flood Control
R - Recreation
W - Water Supply
A - Low Flow Regulation
* - SCS Reservoirs

TABLE 5

GREEN RIVER BASIN

Flow Data 5/

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. 1/ Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yr. Low Flow (cfs)
Green River						
Greensburg, Kentucky 2/	736	1,086	0.4	60,600	1.7	.5
Brownsville, Kentucky 3/	2,762	4,136	120	120,000	141	
Woodbury, Kentucky	5,403	7,979	200	205,000	241	
Livermore, Kentucky 4/	7,564	10,850	280	208,000	306	21
Barren River						
Bowling Green, Kentucky	1,848	2,464	44	85,000	53	32
Nolin River						
Wax, Kentucky	600	790	34	22,000	45	
Rough River						
Dundee, Kentucky	757	963	8.1	20,000	11.1	

1/ Natural flow.
2/ Low flow regulated by Green River Reservoir under construction 1964.
3/ Low flow regulated by Nolin River since 1962 and Green River Reservoir.
4/ Low flow regulated by Rough, Barren, Green and Nolin Rivers.
5/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey."

TABLE 6
GREEN RIVER BASIN
Economic Subarea P

Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation P-1									
Kentucky	Butler	9,600	0						
Kentucky	Hopkins	38,500	18,900						
Kentucky	Logan	20,900	5,900						
Kentucky	Muhlenberg	27,800	6,900						
	Subtotal	96,800	31,700	111,300		143,960		188,000	
Area Designation P-2									
Kentucky	Grayson	15,800	3,000						
Kentucky	Hardin	67,800	13,000						
Kentucky	Larue	10,300	0						
Kentucky	Ohio	17,700	0						
	Subtotal	111,600	16,000	84,150		112,860		153,000	
Area Designation P-3									
Kentucky	Adair	14,700	0						
Kentucky	Allen	12,300	3,300						
Kentucky	Barren	28,300	10,100						
Kentucky	Casey	14,300	0						
Kentucky	Edmonson	8,100	0						
Kentucky	Green	11,200	0						
Kentucky	Hart	14,100	0						
Kentucky	Metcalfe	8,400	0						
Kentucky	Simpson	11,500	5,300						
Kentucky	Taylor	16,300	7,000						
Kentucky	Warren	45,500	28,300						
	Subtotal	184,700	54,000	261,180		341,210		436,000	
Total Subarea P		393,100	102,000	456,630	119,000	598,030	212,000	777,000	411,000

TABLE 7
GREEN RIVER BASIN
Economic Subarea P

Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation P-1													
Kentucky	Butler	2,600	400										
Kentucky	Hopkins	12,100	1,100										
Kentucky	Logan	7,200	1,300										
Kentucky	Muhlenberg	7,400	900										
	Subtotal	29,300	3,700	73.7	121	199	249	168	322	529	225	514	1105
Area Designation P-2													
Kentucky	Grayson	4,400	500										
Kentucky	Hardin	10,800	900										
Kentucky	Larue	3,400	300										
Kentucky	Ohio	5,100	900										
	Subtotal	23,700	2,600	52.6	109	117	202	158	246	431	234	384	895
Area Designation P-3													
Kentucky	Adair	4,400	600										
Kentucky	Allen	4,300	1,000										
Kentucky	Barren	10,000	1,300										
Kentucky	Casey	3,800	600										
Kentucky	Edmonson	2,000	300										
Kentucky	Green	4,000	500										
Kentucky	Hart	4,500	300										
Kentucky	Metcalfe	2,800	300										
Kentucky	Simpson	4,300	900										
Kentucky	Taylor	5,900	1,500										
Kentucky	Warren	16,500	2,800										
	Subtotal	62,500	10,100	179.6	133	169	235	186	256	487	266	354	1025
Total Subarea P		115,500	16,400	305.9	125	167	232	176	272	488	249	396	1022

* In millions of 1960 dollars.
** 1960 = 100

TABLE 8

GREEN RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Breckinridge	N-1	Ohio-Louisville
"	Christian	S-1	Cumberland
"	Cumberland	S-4	Cumberland
"	Daviess	O-3	Lower Ohio-Evansville
"	Hancock	O-3	Lower Ohio-Evansville
"	Henderson	O-2	Lower Ohio-Evansville
"	Lincoln	M-2	Licking-Kentucky-Salt
"	McLean	O-3	Lower Ohio-Evansville
"	Monroe	S-4	Cumberland
"	Russell	S-4	Cumberland
"	Todd	S-1	Cumberland
"	Webster	O-1	Lower Ohio-Evansville
Tennessee	Clay	S-3	Cumberland
"	Macon	S-3	Cumberland
"	Sumner	S-3	Cumberland

GREEN RIVER BASIN
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Avg. (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation P-1											
Kentucky	Butler	1	1,600		1,600	.100		.100	63	Green River	.050
"	Hopkins	3	25,900	1,600	24,300	1.883	.090	1.793	72	Pond River - Lakes - Wells	.280
"	Logan	2	9,810	1,310	8,500	.775	.100	.675	78	Mud River - Springs	.890
"	Muhlenberg	5	13,880	920	12,960	.911	.080	.831	64	Green River - Lakes - Wells	.470
	Subtotal	11	51,190	3,830	47,360	3.669	.270	3.399	72		1.690
Area Designation P-2											
Kentucky	Grayson	1	3,600		3,600*	.240		.240*	67	Impoundments	.070
"	Hardin	1	13,000	13,000		1.000	1.000		77	Wells and Springs	.270
"	Larue	1	2,775		2,775*	.175		.175*	63	North Fork Nolin River	.050
"	Ohio	3	5,105	2,450	2,655	.328	.100	.228	64	Green River - Rough River	.320
	Subtotal	5	24,480	15,450	9,030	1.743	1.100	.643	71		.710
Area Designation P-3											
Kentucky	Adair	1	2,000		2,000	.250		.250	125	Russell Creek	.070
"	Allen	1	4,320		4,320	.400	.400		93	Spring	.080
"	Barren	3	13,785	2,185	11,600	1.270	.470	.800	92	Beaver Creek - Wells	.120
"	Casey	1	1,580		1,580	.175		.175	111	Green River	.040
"	Edmonson	2	625	25	600	.052	.002	.050	83	Green River - Spring	.050
"	Green	1	2,400		2,400	.135		.135	56	Green River	.050
"	Hart	2	3,505	2,375	1,130	.285	.200	.085	81	Green River - Wells	.080
"	Metcalfe	1	770	770		.054	.054		70	Wells	.020
"	Simpson	1	6,845		6,845	.650		.650	95	Drakes Creek - Impoundment	.250
"	Taylor	1	9,450		9,450	1.250		1.250	132	Pitman Creek - Impoundment - Lakes	.130
"	Warren	2	33,800	800	33,000	4.150	.060	4.150	125	Barren River - Wells	.440
	Subtotal	16	79,080	6,155	72,925	8.731	1.186	7.545	111		1.320
Other Areas in Basin											
Kentucky	Breckinridge	1	180	180		.013	.013		70	Springs	
"	Christian	0									
"	Cumberland	0									
"	Daviess	1	740	740		.030	.030		43	Wells	
"	Hancock	0									
"	Henderson	0									
"	Lincoln	0									
"	McLean	3	3,705	555	3,150	.199	.039	.160	54	Green River - Wells	.168
"	Monroe	2	3,300		3,300	.317		.317	96	Line Creek - Mill Creek	.026
"	Todd	0									
"	Webster	0									
Tennessee	Clay	0									
"	Macon	2	3,195	3,195		.192	.192		60	Springs	.156
"	Sumner	2	4,375	4,375		.180	.180		41	Springs	.040
	Subtotal	11	15,495	9,045	6.450	.931	.454	.477	60		.390
	TOTAL	43	170,245	34,480	135,765	15.074	3.010	12.064	89		4.110

*Includes Combined Supplies

TABLE 10

GREEN RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Population Served	Per Capita Use (gpcd)	Total use (mgd)	Population Served	Per Capita Use (gpcd)	Total use (mgd)	Population Served	Per Capita Use (gpcd)	Total use (mgd)	Population Served	Per Capita Use (gpcd)	Total use (mgd)
Area Designation P-1												
From Central Supplies	51,190	72	3.7	59,500	87	5.2	104,200	93	9.7	201,000	98	19.7
Industrial			1.7			4.7			6.8			13.7
Subtotal			5.4			9.9			16.5			33.4
Area Designation P-2												
From Central Supplies	24,480	71	1.7	18,400	86	1.6	34,200	93	3.2	69,000	98	6.8
Industrial			.7			1.4			2.4			4.5
Subtotal			2.4			3.0			5.6			11.3
Area Designation P-3												
From Central Supplies	79,080	111	8.7	110,000	124	13.7	200,000	133	26.6	380,000	139	52.8
Industrial			1.3			3.0			5.1			9.1
Subtotal			10.0			16.7			31.7			61.9
Other Areas in Basin												
From Central Supplies	15,495	60	.9	15,300	71	1.1	22,000	76	1.7	28,600	80	2.3
Industrial			.4			.9			1.5			2.7
Subtotal			1.3			2.0			3.2			5.0
Green River Basin Total												
From Central Supplies Total	170,245	89	15.1	203,200	105	21.6	360,400	115	41.2	678,600	121	81.6
Industrial Total			4.1			10.0			15.8			30.0
GRAND TOTAL			19.2			31.6			57.0			111.6

TABLE 12

GREEN RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation P-1						
Kentucky	Butler	1	1,320	Green River	1,320	1,410
"	Hopkins	1	13,110	Flat & Pond Cr. to Green River	13,110	4,430
"	Logan	1	5,860	Mud & Green River	5,860	5,530
"	Muhlenberg	2	6,795	Cypress Cr. - Pond Cr.	6,795	2,720
	Subtotal	5	27,085		27,085	14,090
Area Designation P-2						
Kentucky	Grayson	1	2,980	Taylor Fork,Bear Creek	2,980	1,450
"	Hardin	1	9,640	Nolin River	9,640	4,280
"	Larue	1	1,985	North Fork Nolin River	1,985	2,070
"	Ohio	2	3,270	Muddy Creek & Rough River	3,270	2,920
	Subtotal	5	17,875		17,875	10,720
Area Designation P-3						
Kentucky	Adair	1	2,255	Russell Creek	2,255	1,900
"	Allen	1	3,325	Barren River	3,325	2,740
"	Barren	1	10,700	Barren River	10,700	5,590
"	Casey	1	1,580	Green River	1,580	1,420
"	Edmonson	0				1,080
"	Green	1	2,335	Green River	2,335	1,810
"	Hart	0				1,030
"	Metcalfe	0				1,090
"	Simpson	1	5,320	Barren River	5,320	3,380
"	Taylor	1	6,900	Little Pitman Creek (G.R.)	6,900	5,170
"	Warren	1	28,340	Barren River	28,340	13,290
	Subtotal	8	60,755		60,755	38,500
Other Areas in Basin						
Kentucky	Breckinridge	0				
"	Christian	0				
"	Cumberland	0				
"	Daviess	0				
"	Hancock	0				
"	Henderson	0				
"	Lincoln	0				
"	McLean	2	2,320	Green River	2,320	2,210
"	Monroe	1	2,090	Green River	2,090	1,720
"	Russell	0				
"	Todd	0				
"	Webster	0				
Tennessee	Clay	0				
"	Macon	0				
"	Sumner	1	2,425	West Fork Drake to Barren River	2,425	1,400
	Subtotal	4	6,835		6,835	5,330
	TOTAL	22	112,550		112,550	68,640

*Not to be interpreted as waste loads to the stream.

TABLE 13
GREEN RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

Raw Waste Production Before Treatment
Population Equivalent*

	1960	1980	2000	2020
Area Designation P-1				
Domestic and Commercial	27,085	31,400	53,000	103,000
Industrial	14,090	37,600	56,000	114,000
Subtotal	41,175	69,000	109,000	217,000
Area Designation P-2				
Domestic and Commercial	17,875	13,400	24,600	50,000
Industrial	10,720	20,600	36,000	69,000
Subtotal	28,595	34,000	60,600	119,000
Area Designation P-3				
Domestic and Commercial	60,755	84,500	153,000	290,000
Industrial	38,500	87,000	148,000	266,000
Subtotal	99,255	171,500	301,000	556,000
Other Areas in Basin				
Domestic and Commercial	6,835	6,800	9,700	12,500
Industrial	5,330	7,000	11,000	15,000
Subtotal	12,165	13,800	20,700	27,500
Green River Basin				
Domestic and Commercial Total	112,550	136,100	240,300	455,500
Industrial Total	68,640	157,000	251,000	464,000
GRAND TOTAL	181,190	293,100	491,300	919,500

*Not to be interpreted as waste loads to the stream.

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OHIO RIVER BASIN COMPREHENSIVE SURVEY. VOLUME V. APPENDIX D. WA--ETC(U)
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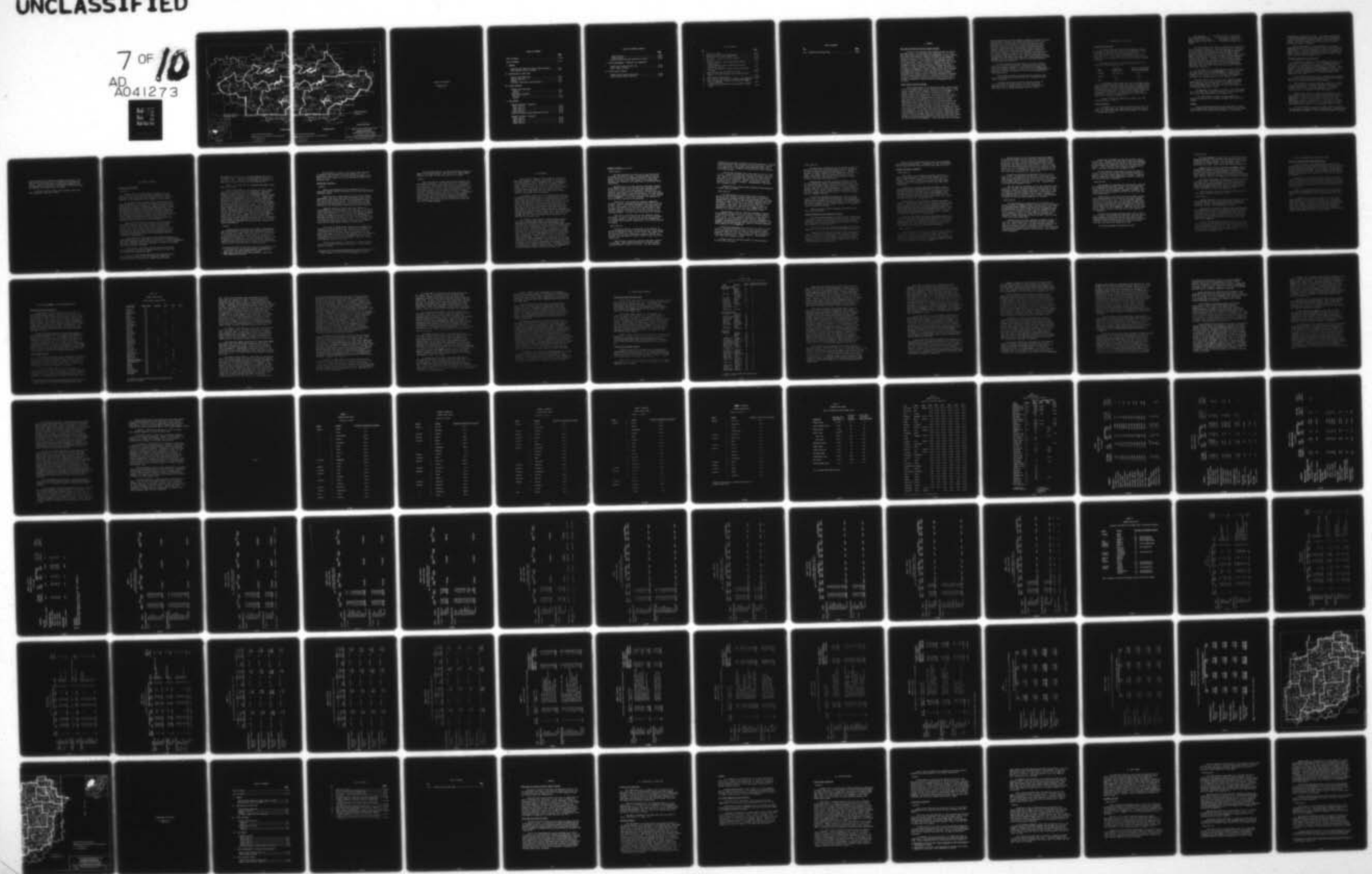

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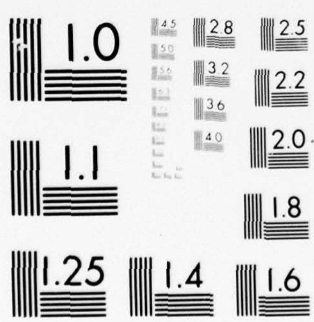
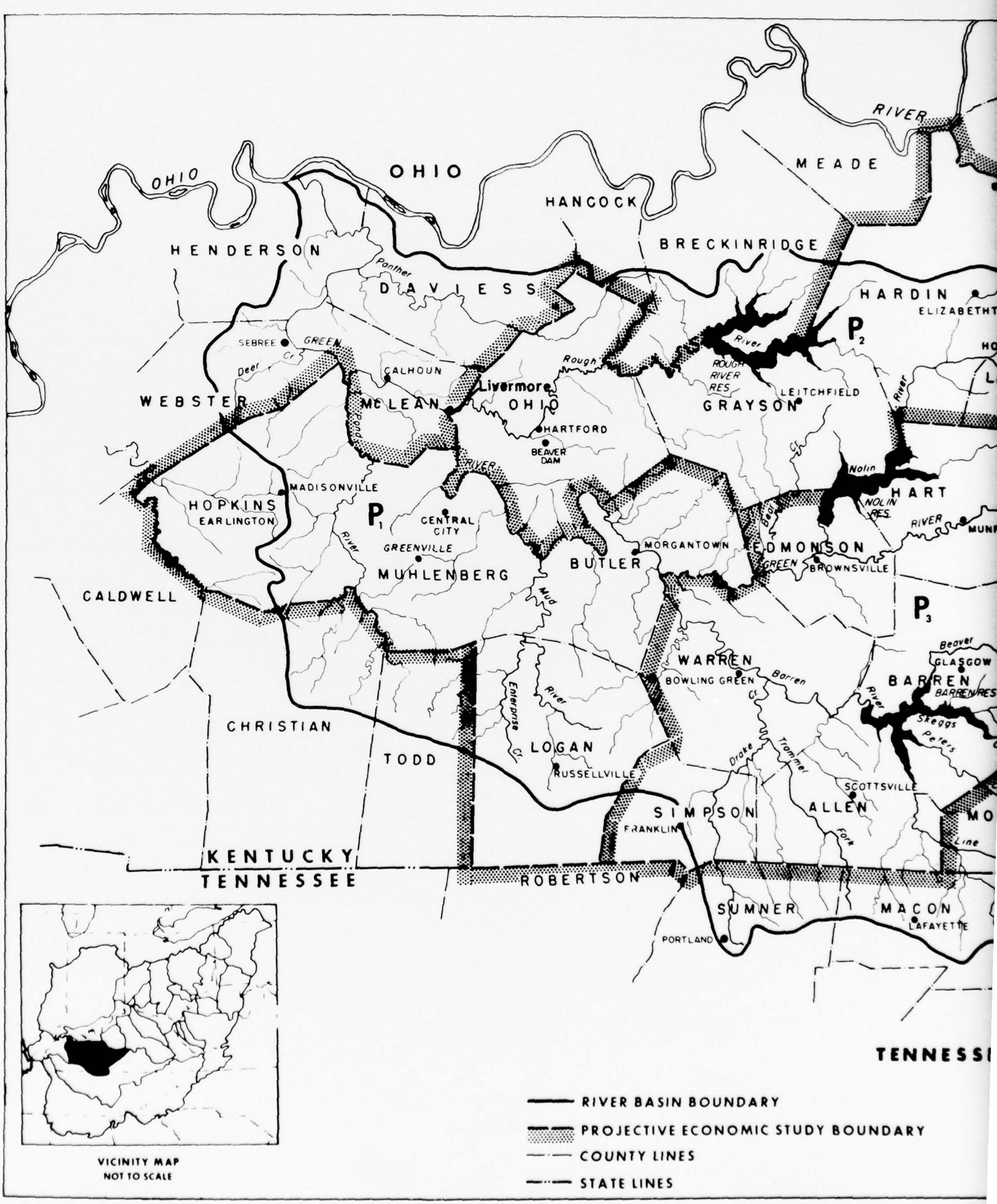
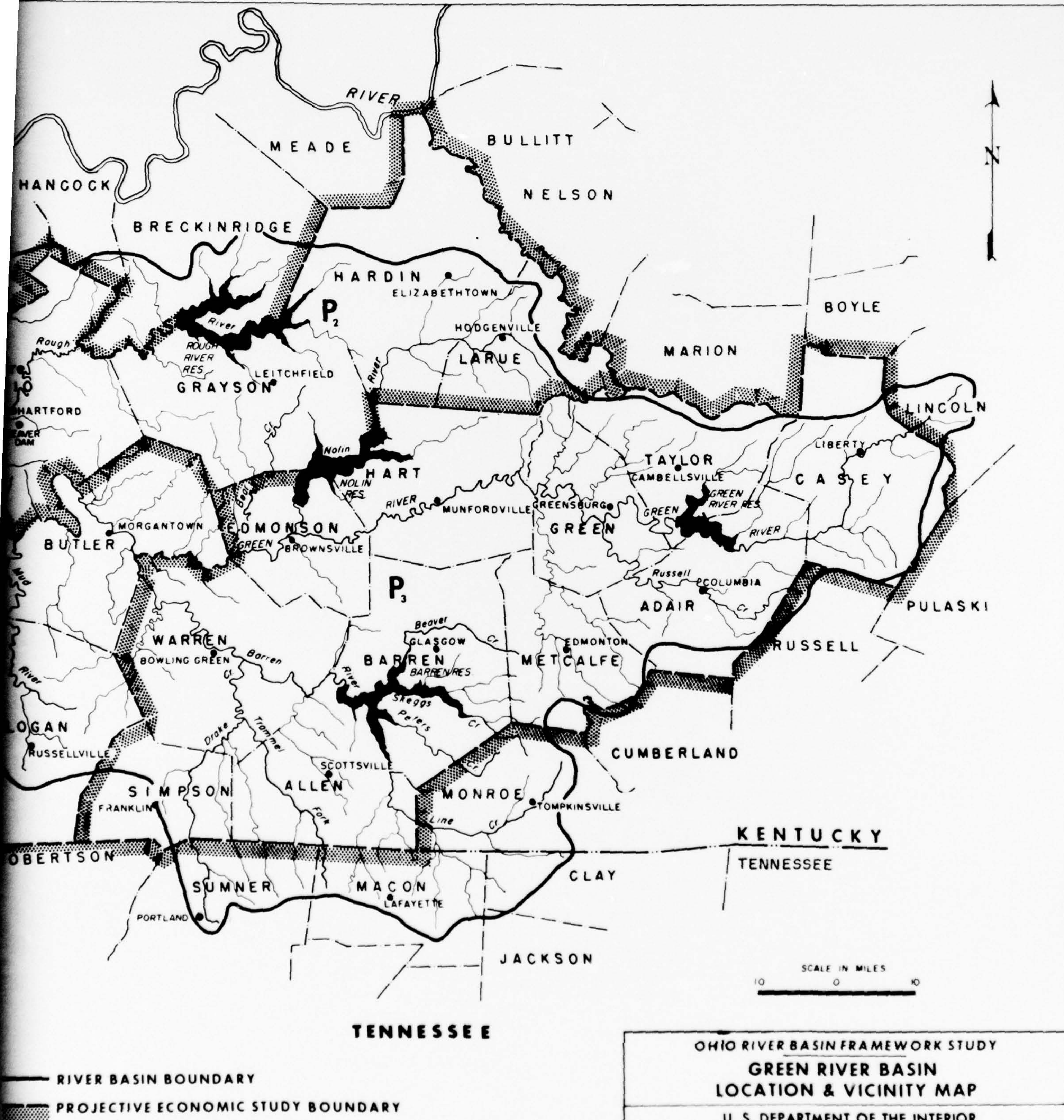


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



OHIO
OHIO
RIVER
MEADE
HANCOCK
BRECKINRIDGE
HENDERSON
DAVIESS
Panther
HARDIN
ELIZABETHTO
P_2
SEBREE
GREEN
Deer Cr.
CALHOUN
Rough
ROUGH RIVER RES
River
LEITCHFIELD
WEBSTER
McLEAN
Livermore
OHIO
GRAYSON
HARTFORD
BEAVER DAM
Pond
RIVER
Nolin
HART
NOLIN RES
RIVER
MADISONVILLE
HOPKINS
EARLINGTON
P_1
CENTRAL CITY
GREENVILLE
MUHLENBERG
River
MORGANTOWN
BUTLER
EDMONSON
GREEN
BROWNSVILLE
CALDWELL
Mud
P_3
WARREN
BOWLING GREEN
Barren
Beaver
GLASGOW
BARREN
BARREN RES.
River
Skeggs
Peters
CHRISTIAN
Enterprise Cr.
River
LOGAN
RUSSELLVILLE
TODD
Drake
Trammel
Cr.
SCOTTSVILLE
SIMPSON
ALLEN
FRANKLIN
Fork
Line
KENTUCKY
TENNESSEE
ROBERTSON
SUMNER
MACON
LAFAYETTE
PORTLAND
TENNESSE
VICINITY MAP
NOT TO SCALE
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STUDY BOUNDARY
COUNTY LINES
STATE LINES



TENNESSEE

RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STUDY BOUNDARY
COUNTY LINES
STATE LINES

OHIO RIVER BASIN FRAMEWORK STUDY

GREEN RIVER BASIN
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

10 29

FIGURE 10.1

WABASH RIVER BASIN

Subbasin Area
No. 11

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I SUMMARY

Municipal and Industrial Water Supply Problems

A total of 347 municipal water systems provide 242 million gallons per day to an estimated served population of 2,117,000. The seven largest systems, supplying Indianapolis, Muncie, Anderson, Terre Haute, and Kokomo in Indiana, and Danville and Champaign-Urbana in Illinois, serve 49 percent of this population with 53 percent of the water. Major industrial use generally centers in these same areas. Points of need for immediate additional sources of supply are Paoli, Austin, Rushville, Anderson, New Castle, Alexandria, Tipton, Marion and Bluffton in Indiana and Olney in Illinois. By 1980, Greenfield, Greenwood, Elwood, Crawfordsville, Huntingburg, Indianapolis, Lebanon, Kokomo, Jasper and Greensburg in Indiana, and Charleston, Paris and Danville in Illinois will need additional supplies. Other communities having somewhat immediately less urgent needs but requiring additional development by 2000 include Speedway, Danville, Franklin, Winchester, Muncie, Princeton, Scottsburg, Sullivan, Hartford City, and Portland in Indiana, and Marshall, Newton, Mattoon, and Champaign-Urbana in Illinois.

Water Quality Control Problems

Major problem areas in the Wabash River Basin, where present critical low summer flows are not sufficient to assimilate residual organics remaining after adequate treatment when discharged to the stream, include reaches of the West Fork White River below Anderson, Muncie and Indianapolis, Indiana, Wildcat Creek below Kokomo, Indiana, Mississinewa River below Marion, Indiana, and the Vermilion River below Champaign-Urbana and Danville, Illinois. Other areas where problems are no less serious but of lesser magnitude are in the West Fork White River below Winchester, Duck Creek below Elwood, Cicero Creek below Tipton, Fall Creek below Lawrence and Ft. Benjamin Harrison, Lick Creek below Beech Grove, Eagle Creek below Speedway, Pleasant Run below Greenwood, Big Walnut Creek below Greencastle, Birch Creek below Brazil and Hawkins Creek below Washington. In the East Fork White River drainage area, present problem areas are the Blue River below New Castle, Brandywine Creek below Greenfield, Flatrock Creek below Rushville, Sugar Creek below Franklin, Sand Creek below Greensburg, Vernon Fork below North Vernon, Stucker Fork below Scottsburg and Austin, Salt Creek below Oolitic, and Clear Creek below Bloomington, Along the main stem of the Wabash

River problem areas are below Bluffton, Huntington and Wabash, Indiana. Along tributary streams in the Indiana problem areas exist in the Salamonie River below Portland, Lick Creek below Hartford City, Mississinewa River below Marion, Little Mississinewa River below Union City, Tippecanoe River below Warsaw, Prairie Creek below Frankfort, Sugar Creek below Crawfordsville, Prairie Creek below Lebanon, Patoka River below Jasper and Huntingburg, and McCarty Ditch below Princeton. Along streams tributary to the Wabash River in Illinois problem areas exist in the South Fork Vermilion River below Rantoul, Sugar Creek below Paris, Lamotte Creek below Robinson, Kickapoo Creek below Mattoon and Charleston, Little Wabash River below Effingham, Fox River below Olney, Seminary Creek below Flora and Johnson Creek below Fairfield.

By 1980, additional problem areas are projected to develop in the Blue River below Shelbyville, Indiana and East Fork White River below Columbus, Indiana. A problem area in the Wabash River below Peru, Indiana, projected to occur by 2000 will be eliminated by completion of Federal multipurpose reservoirs on the Salamonie and Mississinewa Rivers.

Stream quality problems resulting from mine drainage exist in the lower Patoka River and Busseron Creek in Indiana and Sugar Creek in Illinois.

Chloride problem areas resulting from the discharge of oil field brines to streams exist in the lower Patoka and Embarrass Rivers at scattered points in the Little Wabash River and on Big Creek in Indiana and Bonpas Creek in Illinois.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Wabash River Basin extends from Champaign, Illinois, on the west to approximately the eastern boundary of the State of Indiana and from the Ohio River on the south to as far north as Fort Wayne, Indiana, approximately 200 miles in each direction. The total drainage area of the basin is 33,100 square miles and includes all or parts of the 101 counties listed in Table 1.

The following tabulation shows the distribution of the Wabash River drainage area by State:

State	Area in Wabash Basin	Percent of Total State Area in Wabash Basin
Indiana	24,200 sq. mi.	66.9
Illinois	8,560 " "	15.3
Ohio	320 " "	0.8

The headwaters of the Wabash River are in Ohio near Celina. Part of the original headwater area lies within the Grand Reservoir (Lake St. Marys). The main stream flows from its headwaters in a northwesterly direction into Indiana, then across the upper third of Indiana and turns south to form the border between Indiana and Illinois near Terre Haute. It enters the Ohio River above Shawneetown, Illinois, 133 miles upstream of its mouth and 848 miles below Pittsburgh, Pennsylvania.

The main tributaries comprising the Wabash River Basin system are shown in Table 2.

Physical Features

The upper part of the basin lies almost wholly within the State of Indiana except for a small portion within the State of Ohio. The central and lower portions are located in the States of Indiana and Illinois.

The topography is flat to gently rolling in the northern half and southwestern portion of the basin with the Wabash lowlands occupying the extreme southwestern portion. The southeastern portion varies from high flat or rolling uplands to hilly terrain.

All of the Wabash River Basin is underlain with thousands of feet of Paleozoic sandstones, limestones, and shales. Glaciation has had a significant influence upon the landscape in modifying the land surface, providing extensive areas of nearly level plains and reducing the relief of the region through valley filling, even in those sections where glacial deposits did not completely cover the rock surface. In addition to establishing the land surface essentially as it is today, glacial deposition provided the parent material for productive loam soils, provided vast deposits of sand and gravel, and within buried stream valleys that were filled with porous sand and gravel provided extensive ground water resources.

In its course from the headwaters to the mouth, the Wabash River main stem falls at an average slope of 1.1 feet per mile. The upper portion from Bluffton downstream to Lockport has a gradient of 2.6 feet per mile, while the reach from Lockport to the mouth has an average gradient of 0.68 feet per mile.

The West Fork of the White River has a somewhat steeper gradient of 4.8 feet per mile throughout its length from Selma to its confluence with the East Fork. The East Fork of the White River averages about 0.92 feet per mile from Columbus to its confluence with the West Fork.

The Embarrass River located in Illinois in the southwestern part of the basin has a gradient of about 1.4 feet per mile from Villa Grove to the confluence with the Wabash River.

A few lakes formed as a result of the disruption of drainage by glaciation are located in northern basin counties in Indiana.

Climate

The mean annual precipitation varies from about 36 inches in the northern part of the basin to about 40 inches in the central and 44 inches in the extreme southern portion. July rainfall

averages about the same in all areas. The greater precipitation in the south compared with the north comes in the winter months. Southern Indiana has the greatest rainfall in March and least in October. The wettest month in northern and central Indiana is June and the driest is February.

Annual precipitation is usually adequate but an uneven distribution within the year occasionally limits crops and ground water supplies. A drought occasionally occurs in the summer when evaporation is highest and dependence on rainfall is greatest for crops. Average annual temperatures range from a minimum of about 22°F in January to 90°F maximum in July.

Principal Communities and Industries

Agriculture is important in the economy of the basin. The northern portion of the basin is in what is commonly called the "corn belt." A prosperous agricultural economy based on corn, soy beans, and stock raising is established in this area. Truck farming is locally important and is associated with nearby canning plants. These operations are somewhat dispersed in the basin, with the greatest concentration in the headwater areas of the Wabash and White Rivers.

In the southern counties, due to a generally rugged terrain and thin soil cover, more of the acreage is given over to woodland and other less intensive agricultural development.

Coal production is locally important in portions of south-west and west-central Indiana and in an east-central portion of Illinois near Danville. Crude oil production in southeast Illinois in the Little Wabash and Embarrass River Basin and in areas of south-west Indiana is locally significant.

Manufacturing industry is widely diversified as to type and location. Generally, the northern and northeastern headwater portions of the basin have the greatest industrial and urban development. Of the 31 principal communities of over 10,000 population, 23 are on, or northeast of, a northwest to southeast axis running through Champaign, Illinois, and Columbus, Indiana. This axis divides the area in two approximately equal portions.

The well-developed agricultural economy supports a significant and dispersed canning industry in Indianapolis. Pharmaceuticals are important in Indianapolis, Terre Haute, and Lafayette, Indiana.

Pulp and paper product plants are important at Carthage in the East Fork of White River Basin, at Terre Haute and Vincennes, Indiana. Electrical machinery, transportation equipment, and metal fabrication industries are significant in many of the large and moderate sized communities of the basin.

Listed in Table 3 are some of the principal cities and their populations from 1910 to 1960.

III WATER RESOURCES

Surface Water Resources

Quantity

Surface flows in the West Fork of the White River are affected by reservoirs constructed above Indianapolis. Geist Reservoir on Fall Creek and Morse Reservoir on Cicero Creek are operated by the Indianapolis Water Company for water supply.

In the upper basin, reservoirs under construction by the Corps of Engineers are located on the Salamonie, Mississinewa and Wabash Rivers and will be operated to control flood flows in the upper Wabash River Basin. In addition, seasonal storage is being provided in the Salamonie and Mississinewa Reservoirs for low flow regulation during low flow periods. Reservoirs constructed and operated by the Corps of Engineers on tributary streams in the basin are Monroe Reservoir on Salt Creek, Cagles Mill Reservoir on Mill Creek, and Mansfield Reservoir on Raccoon Creek. All three reservoirs are operated for flood control and Monroe and Mansfield are also operated for low flow regulation.

Among future multipurpose reservoirs being considered by the Corps of Engineers are sites in Indiana on Clifty Creek, Patoka River, Wildcat Creek, Big Pine Creek, Big Blue River, Flatrock River and Big Walnut Creek, and in Illinois on the Embarrass River and two sites on the Little Wabash River. Eagle Creek reservoir presently under construction in Marion County, Indiana is a multipurpose project of the Indianapolis Board of Flood Control Commissioners.

Larger reservoirs constructed for water supply storage are Prairie Creek Reservoir, Kokomo Water Works Reservoir on Wildcat Creek, Lake Lemon, Lake Sara, Lake Mattoon and Lake Vermilion, serving respectively the cities of Muncie, Kokomo and Bloomington in Indiana and Effingham, Mattoon and Danville in Illinois.

Two reservoirs, Lake Shafer and Lake Freeman, are located on the Tippecanoe River in the northern portion of the basin and are operated for hydroelectric power.

There are a few natural lakes in the northern part of the basin which are primarily used for recreation. Grand Lake Reservoir in Ohio, constructed as a feeder lake for the now

abandoned Ohio-Erie Canal, includes the original headwaters of the Wabash River. This lake is now operated for recreation by the State of Ohio. There are also many lakes in the remaining portions of the basin constructed for recreational use.

Table 4 shows pertinent data regarding lakes and impoundments in the basin.

Base streamflows[1] in the Wabash Basin are highly variable because of the geologic diversity of the area. Presence or absence of morainal deposits, soil permeability above till deposits, valley alluvium and, in the southern portions, storage in creviced limestone greatly affect low flows. Streams with good low flow characteristics (over 0.1 cfs per square mile at 90 percent flow duration) include the Tippecanoe River, the Eel River of the North, the West Fork of White River, and upper portions of the East Fork of White River. All of these streams are in the more heavily glaciated northern areas. The upper and middle Wabash River also have low flow characteristics in this range. Streams with moderate low flow characteristics (0.05 to 0.10 cfs per square mile at 90 percent flow duration) include the Eel River of the South, the Salamonie and Mississinewa Rivers, and Sugar Creek. Streams with poor low flow characteristics (below 0.05 cfs per square mile at 90 percent flow duration) include Eagle and Raccoon Creeks, and the Muscatatuck, Little Wabash, Patoka, Embarrass, and Vermilion Rivers. Table 5 shows stream data excerpted from hydrology data prepared by the Corps of Engineers.[2]

Quality

Surface waters in the basin are primarily hard waters of the calcium-magnesium bicarbonate type, generally ranging from 200 to 400 mg/l in the glaciated areas and from 100 to 300 mg/l in the nonglaciated areas. Natural variations in quality occur as the percentage of softer surface runoff to ground water contribution in streams vary. Quality changes are also a result of domestic and industrial wastes below the larger population centers and downstream from smaller communities in stream reaches where low flows are insufficient to assimilate wastes.

1/ Flow duration data is reported on plate 20 of Appendix E Ground-Water Distribution and Potential in the Ohio River Basin, Ohio River Basin Comprehensive Survey.

2/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

Mine drainage is a factor in the lower Patoka River and in Busseron Creek and some other small streams. Oil field wastes affect water quality in portions of the Embarrass, Patoka, and Little Wabash Rivers as well as in some small streams in oil producing areas.

Ground Water Resources

Quantity

Ground water resources have been reported by the U. S. Geological Survey1/ and the following discussion has been condensed from their report.

Large supplies of ground water are available for further development in the basin, with excellent sources located in most parts of the basin except for about 13,000 square miles south of the limit of Wisconsin glaciation. The distribution of ground water favors the northeastern part of the basin which has good aquifers in both unconsolidated sediments and bedrock formations.

Important supplies of ground water are available in outwash deposits in the Tippecanoe River Valley and in the Wabash River Valley from near Fort Wayne to the confluence of the Wabash River with the Ohio River. In the White River subbasin, important supplies of ground water are also available for development in the upper West Fork of the White River and East Fork of the White River and in the valley of the White River. The preglacial valley of the ancient Teays River, contains thick deposits of sand and gravel and is a good source of water, in certain areas.

The sources of ground water listed above can generally be expected to yield in excess of 100 gallons per minute (gpm) and in some areas as much as 1,500 gpm. In addition over much of the northern half of the basin, lenses of saturated sand and gravel interbedded with the much less permeable till were deposited. These lenses are not as thick as the major aquifers previously discussed and are not as readily recharged. Many wells tapping these deposits yield 20 to 100 gpm.

The principal sources of ground water in bedrock include extensive limestone formations particularly in the northeastern part of the basin.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

Fracture zones and solution channels containing water are common in the shallow strata. Most of the wells tapping these strata in the upper 300 feet yield from 150 to 500 gpm.

Quality

Water from both the unconsolidated glacial deposits and from bedrock formations is very hard, generally in the range of 250 to 500 mg/l. Total dissolved solids are in the moderately high range of 300 to 600 mg/l. Chlorides are typically in a low range, below 25 mg/l. Iron is often in the range of 1 to 3 mg/l which makes treatment for iron removal desirable in domestic supplies. Sulfates generally range below 100 mg/l. An exception to the general water quality is an area in the far northeast portion of the basin where bedrock, limestone and dolomite deposits yield waters with a sulfate content often above the Public Health Service Drinking Water Standards of 250 mg/l and total solids above 500 mg/l.

IV THE ECONOMY

The Projective Economic Study divided the Wabash River Basin into Subarea Q, the White and Subarea R, the Wabash. The White subarea is nearly coextensive with the watershed of the White River subbasin in Indiana and the Wabash subarea is roughly coextensive with the rest of the watershed of the Wabash River in Indiana and Illinois. To facilitate estimates of future water requirements and waste loads, the White Subarea Q was divided into four minor areas and the Wabash Subarea R was divided into six subareas.

In Subarea Q, minor area Q-1 includes the nine counties encompassing the drainage area of the lower portion of the West Fork of the White River and the main stem White River and the lower Wabash main stem drainage in Indiana including most of the Patoka River subbasin, a tributary of the Wabash River. Minor area Q-2 includes twelve counties that roughly describe the East Fork of the White River drainage area excepting the headwater region of the Driftwood River, an East Fork tributary. Minor area Q-3 includes eight counties centered on Indianapolis, Indiana, and includes the middle portion of the East Fork drainage area and the headwater of the Driftwood River. Minor area Q-4 includes the four counties encompassing the headwater of the East Fork of the White River.

In Subarea R, minor area R-1 includes eleven counties in Illinois, encompassing roughly the lower portion of the Embarrass River and Wabash River main stem drainage areas. Minor area R-2 includes three Illinois counties and three Indiana counties roughly encompassing the lower portion of the central Wabash River main stem drainage area. Minor area R-3 includes four counties in Illinois which roughly encompasses the upper Embarrass River drainage area and the Vermilion River drainage area. Minor area R-4 includes twelve counties in Indiana which roughly encompasses the upper portion of the central Wabash River drainage area. Minor area R-5 includes six counties in Indiana which roughly encompasses the lower portion of the headwater region of the Wabash River. Minor area R-6 includes four counties in Indiana roughly encompassing the headwater region of the Wabash River. Shown in Tables 6 and 7 is a complete listing of the counties included in each minor area. The boundaries of the minor areas are shown on Figure 11-1, page 11-48.

Economic Profiles - Subarea Q

Minor Area Q-1

The 1960 population in minor area Q-1 was 225,200 with 37 percent classified as urban. Average personal per capita income amounted to $1,483 compared to $1,832 in the State of Indiana. Two larger cities are located in this minor area, Washington and Vincennes, with populations of 10,800 and 18,000 respectively.

Manufacturing is the most important employment category. Establishments employing 100 workers or more increased from 36 in 1958 to 41 in 1964. The most important industries are machinery (including electrical machinery), furniture and wood products, other durables, and food processing. The three thermal power generating plants located in the area have a total capacity of 186.5 megawatts. A new plant scheduled to be operative in 1967 will have a capacity of 220 megawatts.

Agriculture is the second most important employment category. However, employment decreased from 17,300 in 1950 to 11,100 in 1960. Land in farms decreased 67,000 acres from 1954 to 1959. Nevertheless, the total value of farm products sold increased from $73.9 million in 1954 to $89.7 million in 1959. Fifty-five percent of the latter figure was accounted for by livestock products. In 1959, about 1,200 acres were irrigated.

Coal and oil extraction are the most important mining activities. In 1960, 5.6 million tons of coal and an estimated 3.1 million barrels of crude oil were produced, representing 36.5 percent and 25 percent, respectively, of the totals produced in Indiana.

Minor Area Q-2

The 1960 population in minor area Q-2 was 299,200, 39 percent classified as urban. Average personal per capita income was $1,577 compared to $1,832 for the State. Four larger cities are located in the area, Bloomington, Columbus, Bedford, and Seymour, with populations of 31,400, 20,800, 13,000, and 11,600 respectively.

Manufacturing is the most important employment category in this area. Establishments employing 100 or more workers increased from 65 in 1958 to 73 in 1964. The most important

industries are machinery (including electrical machinery), furniture and wood products, other durables, and food processing. Located in the minor area is one thermal power generating plant with a total capacity of 8.3 megawatts and one pulp mill with a capacity of 100 tons per day.

Agricultural employment fell from 17,600 in 1950 to 11,000 in 1960. During the period 1954-1959, 165,000 acres of farm land were taken out of farm production. However, the total value of farm products sold increased from $71.8 million in 1954 to $82 million in 1959. Sixty-five percent of the latter figure was accounted for by livestock products. Approximately 1,300 acres were irrigated in 1959.

Mining activity is almost wholly confined to the extraction of stone, sand, and gravel.

Minor Area Q-3

The 1960 population of this minor area was 944,500, 74 percent of which resided in Marion County which is designated the Indianapolis Standard Metropolitan Statistical Area. Average personal per capita income in Marion County was $2,188 and in the remaining counties of the area it was $1,810 compared to $1,832 for Indiana. Four larger cities are located in the area, Indianapolis, Beech Grove, and Lawrence in Marion County with populations of 476,300, 11,000, and 10,100 respectively, and Shelbyville in Shelby County with a population of 14,300.

Manufacturing is the most important employment category. Establishments employing 100 or more workers increased from 154 in 1958 to 182 in 1964. Of the 28 new plants, 17 are located in Marion County. The most important industries are machinery (including electrical machinery), motor vehicles, transportation equipment, pharmaceuticals and chemicals and allied products. Six thermal power generating plants are located in the area, having a total capacity of 930.5 megawatts.

Agricultural employment fell from 17,700 in 1950 to 11,700 in 1960. During the period 1954-1959, 56,000 acres were taken out of farm production, but the value of farm products sold has remained at about the 1959 figure of $91.7 million, 58 percent of which was accounted for by livestock products. Approximately 1,600 acres were irrigated in 1959.

Mining activity is confined primarily to the extraction of stone, sand, and gravel.

Minor Area Q-4

The population of minor area Q-4 was 314,000 in 1960, 35.2 percent of which lived in Delaware County, which is designated the Muncie Standard Metropolitan Statistical Area. Average personal per capita income was $1,860 compared to $1,832 for the State. Four larger cities are located in the area, Muncie, Anderson, New Castle, and Elwood, with populations of 68,600, 49,100, 20,300, and 11,800 respectively.

Manufacturing is the most important employment category. The most significant change in establishments employing 100 or more workers has been a shift from smaller plants to larger ones. In 1964, there were 63 plants employing 100 or more employees. The most important industries are machinery (including electrical machinery), motor vehicles, other durables, and primary metals. One small thermal power generating plant is located in the area with a 10 megawatt capacity.

Agricultural employment decreased from 9,200 in 1950 to 6,400 in 1960. During the period 1954-1959, 16,000 acres were taken out of farm production, but the value of farm products sold has remained at about the 1959 figure of $50.4 million, 56 percent of which is accounted for by livestock products. In 1959, less than 300 acres were irrigated.

Mining activity is mainly confined to the extraction of stone, sand, and gravel.

Projected Population and Industrial Activity

The White subarea population is projected to increase from 1.8 million in 1960 to 4.1 million by 2020. In 1960, the subarea contained 9.4 percent of the total Ohio River Basin population. It is projected to contain 11.8 percent of the total Ohio River Basin population by the year 2020.

Table 6 shows the 1960 and projected population for minor areas Q-1, Q-2, Q-3, and Q-4 as well as the totals for Subarea Q.

According to the Projective Economic Study, agricultural output is projected to increase from $380.7 million in 1960 to $549.1 million by 2010; mining output is projected to increase from $115.1 million in 1960 to $889.3 million by 2010; and manufacturing output is projected to increase from $5.5 billion in 1960 to about $32 billion by 2010.

Table 7 shows 1960 manufacturing output, total employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

Economic Profiles - Subarea R

Minor Area R-1

Minor area R-1 is a relatively sparsely settled area, having a 1960 population of 165,200 and an average personal per capita income of $1,441 compared to $2,181 for the State of Illinois. The larger cities in the area are Effingham, Olney, and Mount Carmel with populations of 8,170, 8,800, and 8,600 respectively.

Agriculture is the most important employment category. Although employment decreased from 18,500 in 1950 to 11,300 in 1960 and 21,000 acres were taken out of farm production during the period 1954-1959, the total value of farm products sold increased from $63.1 million in 1954 to $87.1 million in 1959. Fifty-six percent of the latter figure is accounted for by crops. Less than 350 acres were irrigated in 1959.

Manufacturing is the second most important employment category. Establishments employing 100 or more workers increased from 17 in 1958 to 25 in 1964. The most important industries are other nondurables, machinery (including electrical machinery), apparel and other fabricated clothing, and motor vehicles. Three thermal power generating plants are located in the area with a total capacity of 43.2 megawatts and one pulp mill is located in the area with a capacity of 25 tons per day.

Crude oil and natural gas extraction dominate the mining industry in the area. Data are not available on the county basis, but it is estimated that approximately 60 percent of the total production (78.8 million barrels) in Illinois in 1960 originated in minor area R-1. Other than petroleum mining, there was a small amount of extraction of stone, sand, and gravel.

Minor Area R-2

The 1960 population amounted to 222,600 in this minor area, 48.6 percent residing in Vigo County, Indiana, designated as the Terre Haute Standard Metropolitan Statistical Area. Average personal per capita income amounted to $1,742 in Vigo County and $1,499 in the remaining counties in Indiana and Illinois compared to $2,181 in Illinois and $1,832 in Indiana.

Manufacturing is the most important employment category. Establishments employing 100 or more workers increased from 39 in 1958 to 46 in 1964. The most important industries are food processing, machinery (including electrical machinery), other nondurables, and chemicals and allied products. There are seven thermal power generating plants located in the area with a total capacity of 1,471.1 megawatts and one addition scheduled for 1968 with a capacity of 318 megawatts. There is one pulp mill in the minor area with a capacity of 150 tons per day.

Agricultural employment decreased from 12,900 in 1950 to 8,200 in 1960. During the period 1954-1959, 20,000 acres were taken out of farm production, but the total value of farm products sold increased from $66.6 million to $71.9 million, 58.3 percent of the latter figure is accounted for by crops. Approximately 1,400 acres were irrigated in 1959.

Coal and crude oil production are the most important mining activities. In 1960, the area produced 3.9 million tons of coal, equaling 25 percent of Indiana's total yearly production but only 8.5 percent of Illinois' yearly production. County data on crude oil production are not available, but the area is estimated to have produced some 11.8 million barrels in 1960, or approximately 15 percent of the total yearly production in Illinois.

Minor Area R-3

The 1960 population in minor area R-3 was 290,700, 45.5 percent residing in Champaign County, Illinois, which is designated the Champaign-Urbana Standard Metropolitan Statistical Area. The average personal per capita income was $1,918 in Champaign County and $1,718 in the remaining Illinois counties compared to $2,181 in the State of Illinois. The six larger cities located in the area are Champaign, Danville, Urbana, Rantoul, Mattoon, and Charleston, having populations of 49,600, 41,900, 27,300, 22,100, 17,500, and 10,500 respectively.

Manufacturing is the most important employment category in this area. Establishments with 100 workers or more increased from 47 in 1958 to 49 in 1964. The most important industries are machinery (including electrical machinery), food processing, printing and allied products, and primary metals. The five thermal power generating plants located in the area have a total capacity of 240.3 megawatts.

Agricultural employment declined from 12,800 in 1950 to 8,800 in 1960. However, the total acres in farm land increased 12,000 in this area between 1954 and 1959, while the total value of farm products sold remained at about the 1959 level of $94.5 million. About 70 percent of this figure is accounted for by crops. Less than 100 acres were irrigated in 1959.

The area produced a small amount of coal and crude oil. In 1960, 1.6 million tons of coal were extracted, equaling 3.5 percent of the total yearly production in Illinois. There was some oil production in Coles and Douglas Counties, but data on the county basis are not available.

Minor Area R-4

The population of minor area R-4 was 214,300 in 1960 and the average personal per capita income in the minor area was $1,703 compared to $1,832 for Indiana. The four larger cities located in the area are Lafayette, Logansport, Frankfort, and Crawfordsville with populations of 42,300, 21,100, 15,300, and 14,200 respectively.

Manufacturing is the most important employment category. Establishments employing 100 workers or more have increased from 40 in 1958 to 59 in 1964. The most important industries are machinery (including electrical machinery), primary metals, printing and allied products, and food processing. There are three thermal power generating plants located in the area with a total capacity of 262.3 megawatts. There are also two hydro-electric plants located in the area with a total capacity of 17.7 megawatts.

Agricultural employment declined from 23,900 in 1950 to 15,700 in 1960. During the period 1954-1959, the total land in farms remained about the same, and the total value of farm products sold has remained at the 1959 level of $171.9 million, 53 percent of which is accounted for by livestock products. Less than 1,200 acres were irrigated in 1959.

No mining employment was reported for 1960.

Minor Area R-5

The 1960 population in minor area R-5 was 277,200 and the average personal per capita income in the minor area was $1,768 compared to $1,832 for Indiana. The four larger cities located in the area are Kokomo, Marion, Peru, and Wabash, having populations of 47,200, 37,900, 14,500, and 12,600 respectively.

Manufacturing is the most important employment category. Establishments employing 100 workers or over increased from 65 in 1958 to 89 in 1964. The most important industries are machinery (including electrical machinery), primary metals, other durables, and motor vehicles. One thermal power generating plant, having a capacity of 40 megawatts, is located in the area.

Agricultural employment has decreased from 14,100 in 1950 to 8,600 in 1960. During the period 1954-1959, 38,000 acres were taken out of farm production, but the total value of farm products sold increased from $82.4 million to $84.7 million. Fifty-eight percent of the latter figure is accounted for by crops. Less than 100 acres were irrigated in 1959.

Mining activity in the area was almost wholly confined to stone, sand, and gravel extraction in 1960.

Minor Area R-6

The 1960 population in this minor area was 92,400 and the average personal per capita income was $1,710 compared with $1,832 for Indiana. The largest city located in the area is Huntington, Indiana, with a population of 16,200.

Manufacturing is the most important employment category, and establishments employing 100 workers or more increased from 27 in 1958 to 38 in 1964. The most important industries are printing and allied products, machinery (including electrical machinery), other durables, and motor vehicles. Two thermal power generating plants are located in the area with a total capacity of 17 megawatts.

Agricultural employment decreased from 7,400 in 1950 to 4,500 in 1960. Between 1954 and 1959, 34,000 acres were taken out of farm production, and the total value of farm products fell from $39.3 million to $34.8 million. About 52 percent of the latter figure is accounted for by livestock products. Less than 100 acres were irrigated in 1959.

No mining employment was reported in 1960.

Projected Population and Industrial Activity

Total population of the Wabash subarea is projected to increase from 1.4 million in 1960 to 2.2 million by the year 2000. The 1960 population accounted for 7.2 percent of the total population of the Ohio River Basin, but the subarea is projected to account for 8 percent by 2020. Shown in Table 6 are the 1960 and projected populations for the minor areas as well as the totals for Subarea R.

According to the Projective Economic Study, agricultural output is projected to increase from $633.3 million in 1960 to $972.6 million by 2010, and mining output is expected to increase from $163.1 million to $2.15 billion by 2010. Manufacturing output is projected to increase from $3.2 billion in 1960 to $18.2 billion by 2010.

Table 7 shows 1960 manufacturing output, total employment and manufacturing employment. Projections to 1980, 2000, and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the White and Wabash subareas in the Projective Economic Study, twenty-four other counties have land area within the basin. These counties are listed in Table 8. Some of these counties have significant water using communities and significant sources of pollution within the basin, and projections of their water needs and organic waste loads are based on the projections of the Projective Economic Study subarea in which they are located.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

Approximately 2,117,000 people are served by the 347 central water supply systems of the basin. While only 51 (or 14.7 percent) of these systems utilize surface sources of supply, they provide 64 percent of the 242 mgd of water supplied from central sources. The 7 largest systems, serving Indianapolis, Muncie, Anderson, Terre Haute, Danville, Kokomo, and Champaign-Urbana, serve 49 percent of the population supplied from central sources and 53 percent of the centrally supplied water. The present municipal and industrial water use estimates for the basin are listed by county and totaled for economic subareas in the basin in Table 9.

Based on projected population increase and industrial activity, estimated water use will increase in the Wabash River Basin as shown in Table 10. It is estimated that the total municipal and industrial water requirements in the basin will increase 4.5 times by 2020 with the increase projected to over 5.5 times in minor areas Q-1, Q-2, R-1 and R-2, to over 4.5 times in minor areas R-3 and R-4, to over 4 times in minor areas Q-4 and R-6, and over 3.5 times in minor areas Q-3, R-5 and other areas in the basin not included in the Projective Economic Study area. The major increases will probably occur in or about the present centers of population and industrial activity.

Water Supply Problems

The projected total water supply figures shown in Table 10, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11 are problem areas with the approximate time of onset.

In Indiana in minor area Q-1, the total water use is projected to increase to 36.5 mgd by 1980, 63.1 mgd by 2000, and to 108.1 mgd by 2020. Projected needs are fairly well dispersed throughout this area where no city presently has over 20,000 population. Developable sources of supply can meet most of this

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11

WABASH RIVER BASIN

Water Supply Problem Areas

Vicinity 1/	Minor Area	Present	1980	2000	2020
Princeton	Q-1			X	
Jasper	Q-1		X		
Huntingburg	Q-1		X		
Linton	Q-1				X
Paoli	Q-2	X			
Scottsburg	Q-2			X	
Austin	Q-2	X			
Greensburg	Q-2		X		
Rushville	Q-2	X			
Indianapolis	Q-3		X		
Speedway	Q-3			X	
Danville	Q-3			X	
Lebanon	Q-3		X		
Franklin	Q-3			X	
Greenfield	Q-3		X		
Greenwood	Q-3		X		
Muncie	Q-4			X	
Anderson	Q-4	X			
New Castle	Q-4	X			
Winchester	Q-4			X	
Alexandria	Q-4	X			
Elwood	Q-4		X		
Olney 2/	R-1	X			
Paris 2/	R-2		X		
Marshall 2/	R-2			X	
Sullivan	R-2			X	
Charleston 2/	R-3		X		
Mattoon 2/	R-3			X	
Newton 2/	R-3			X	
Danville 2/	R-3		X		
Champaign-Urbana 2/	R-3			X	
Crawfordsville	R-4		X		
Tipton	R-4	X			
Kokomo	R-5		X		
Marion	R-5	X			
Bluffton	R-6	X			
Hartford City	R-6			X	
Huntington	R-6				X
Portland	R-6			X	

1/ Located in State of Indiana unless otherwise noted.
2/ State of Illinois

need. Within this downstream area, the Wabash River, White River, East Fork White River, and Eel River are capable of supplying major quantities of water. Ground water yields in significant quantity can be further developed along these same streams. Areas with future needs above present supply are centered on Jasper, Huntingburg, Linton, and Princeton. For Linton, where additional supply will be needed by 2020, a pipeline to White River is a potential source of supply, if needs cannot be met in the local area. Princeton's needs must be met by 2000 and alternatives for future supply include pipelines to the White or Wabash Rivers or improvement of the Patoka River to a quality satisfactory for water supply purposes by pollution abatement at upstream points. Jasper and Huntingburg, located in the Patoka River subbasin, by 1980 will need additional sources of supply and can probably develop local or upstream impoundments. As an alternative to upstream impoundments, allocation of water supply storage in Federal reservoirs can meet their needs.

In Indiana in minor area Q-2, total water use projections are for 64.6 mgd by 1980, 112.1 mgd by 2000, and 190.4 mgd by 2020. The major water use areas will probably be at Columbus and Bloomington where existing surface sources and present and expected ground water development is capable of meeting future needs. Areas of need for further development of sources of supply are Paoli, Scottsburg, Austin, Greensburg, and Rushville.

Austin and Paoli have a present need for source development and future needs will develop at Greensburg by 1980 and at Scottsburg, and Rushville by 2000. These needs will probably have to be satisfied from storage, probably by construction of local impoundments. Consideration should also be given to the possibility of Austin and Scottsburg future needs being satisfied by the Ohio River or the glacial and alluvial deposits along the Ohio River.

In Indiana in minor area Q-3, total water use projections are for 235.7 mgd by 1980, 363.4 mgd by 2000, and 616.2 mgd by 2020. The area of greatest need is the Indianapolis metropolitan area where by 1980 additional supplies will be needed. Since this minor area is located essentially in a headwater area and present surface supplies are nearly fully utilized in the White River Basin above Indianapolis, significant future development of both ground and surface water sources will be required to meet these needs. Perhaps, as increasingly more costly water supply sources are developed and water becomes more expensive, more industrial in-plant reuse and other water conservation measures may take place. This would result in the possibility

of a lower projected future water use, even with the projected population growth and industrial development. Indianapolis is located in an area where ground water is a significant factor in the total water supply. However, it is noted that emphasis has shifted from ground water supply to development of surface storage. For further development of surface sources, Indianapolis may be required to look to adjacent tributary drainage subbasins and, as an alternative to construction of single-purpose impoundments, could seek water supply storage in Federal multipurpose reservoirs. In addition to Indianapolis, source needs will develop in the communities of Lebanon, Greenwood and Greenfield by 1980, at Franklin, Speedway, and Danville by 2000. These communities are located immediately outside the Indianapolis metropolitan area. Lebanon, as an alternative to ground water development, could develop water supply storage in local impoundments. Franklin located in the Driftwood River subbasin and Greenfield in the Big Blue River subbasin could develop local surface impoundments or as an alternative look to development of water supply storage in Federal multipurpose reservoirs being studied in the subbasin. Greenwood probably could develop additional ground sources but may find within the study period that connection to the Indianapolis water system may prove feasible.

In Indiana in minor area Q-4, which includes the extreme headwater areas of the White and East Fork White Rivers, total water use is projected to increase to 64.2 mgd by 1980, 96.1 mgd by 2000, and 121.6 mgd by 2020. All of the larger communities are expected to require significantly more water supply and areas of need center in Alexandria, Anderson and New Castle at the present, Elwood by 1980, and Winchester and Muncie by 2000. Although in an area where ground water appears to be plentiful, Muncie, Anderson and New Castle may find that due to the extensions required to develop dependable well fields, it may be more economical to look to surface sources in Federal reservoirs or local impoundments. Alexandria, Elwood and Winchester can probably meet future need by expansion of ground water sources.

In Illinois in minor area R-1, the total water use projections are for 27.1 mgd by 1980, 47.4 mgd by 2000, and 77.2 mgd by 2020. The Wabash River and Little Wabash River can supply a large part of this projected need. The only area with significant source development needs is at Olney, Illinois. Needs are immediate and can probably be met from development of local impoundments or storage in a Federal reservoir.

In minor area R-2, total water use projections are for 97.3 mgd by 1980, 171.8 mgd by 2000, and 312 mgd by 2020. Terre Haute, Indiana, the largest city in the area, can be adequately served by surface and ground water sources along the Wabash River. At Paris, Illinois by 1980 and Marshall, Illinois and Sullivan, Indiana by 2000, additional supply sources may be required. For Marshall and Sullivan, alternatives for future development include local impoundments and a pipeline to the Wabash River valley for development of ground water or surface sources. Paris will probably have to develop local impoundments.

In Illinois in minor area R-3, the total water use is projected to increase to 109 mgd by 1980, 185.9 mgd by 2000, and 328.5 mgd by 2020. Major water use areas at present are Champaign-Urbana and Danville which use 74 percent of the centrally supplied water in the R-3 minor area. Present surface water sources will need to be supplemented at Danville by 1980. At Champaign-Urbana, additional development of ground water, perhaps supplemented with surface supply, will be necessary by 2000. Lesser points of need within this area where source of supply development will be required include Charleston by 1980 and Mattoon and Newton by 2000. These needs can possibly be supplied from Federal reservoirs.

In Indiana in minor area R-4, the total water use is projected to increase to 58.6 mgd by 1980, 97.8 mgd by 2000, and 157.7 mgd by 2020. Ground water is generally available in significant quantities in this area, with Logansport the only central supply using surface water. Additional water supply potential exists in the Wabash and Tippecanoe Rivers which have good base flow characteristics. Because of the generally good availability of water supply sources, only the upstream communities of Tipton at present and Crawfordsville by 1980 are expected to have any source of supply development problems. Tipton can probably expand its present ground water sources to meet future needs, while Crawfordsville will need to develop local or other surface impoundments to meet future needs.

In Indiana in minor area R-5, the total water use is projected to increase to 80.9 mgd by 1980, 120 mgd by 2000, and 167 mgd by 2020. Within this area, the Wabash, Eel, and Mississinewa Rivers have sufficient base flows for significant use. In addition, ground water supplies are generally excellent. Marion has a present need for source development. The industrialization and growth of Kokomo by 1980 is expected to make source development required for its future growth.

Marion, located in the Mississinewa River subbasin, presently using ground sources, can probably develop additional well fields to meet future needs. Should Marion elect to develop surface supplies, storage in local impoundments or reallocation of storage in Federal reservoirs in adjacent watershed areas can meet these needs.

Kokomo, located on Wildcat Creek, a tributary of the Wabash River, at present uses both surface and ground water sources for supply. Expansion of ground water sources will probably have to be in bedrock aquifers as the unconsolidated materials in the area are not considered reliable sources of water. Development of additional surface sources will probably involve local impoundments on adjacent tributary streams or possibly reallocation of storage in a Federal reservoir in a nearby drainage area.

In Indiana in minor area R-6, the total water use is projected to increase to 15.4 mgd by 1980, 26 mgd by 2000, and 35.2 mgd by 2020. This is the headwater area of the Wabash River and the surface water potential is limited. However, ground water is generally relatively abundant. Additional source of supply development is required by Bluffton at present and is also expected to be required near the end of the study period at Hartford City and Portland by 2000 and Huntington by 2020. Bluffton, Hartford City and Portland presently depend on ground sources for supply. Availability of ground water in unconsolidated sediments and in bedrock appear to be adequate to meet future needs. Huntington at the present relies on combined ground and surface sources for water supply. Adequate supplies of ground water appear to be available in both the unconsolidated sediments and in the bedrock formations. Should Huntington elect to develop its surface supply further, its close proximity to the Huntington Reservoir, a Federal multipurpose project, can meet this need.

In addition to the communities within the counties included in the ten economic subareas, a number of communities are physically in the Wabash Basin but included in other economic subareas. No major unmet needs are evident for these communities. The largest such community is Celina, Ohio, whose present source of supply, Grand Lake, should be adequate for future needs.

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

Present waste loads generated are shown in Table 12. In the basin as a whole, organic waste loads from municipal and industrial waste sources are approximately equal. The metropolitan Indianapolis area and the surrounding counties designated as the Q-3 minor area account for about one-third of the domestic and commercial and almost one-half of the industrial organic load of the entire Wabash Basin.

In all minor areas, except Q-3, R-2, and R-5, the industrial organic waste loading is in the general range of 50 to 75 percent of the domestic and commercial loading. In the Q-3 minor area, meat packing, pharmaceutical, and paper plant wastes in Indianapolis are responsible for much of the industrial loading. In minor area R-2, paper plant, canning, and pharmaceutical wastes at Terre Haute are responsible for a relatively high ratio of industrial to domestic wastes. In minor area R-5, paper and acoustical tile plants constitute relatively large loadings in Wabash County which result in a larger industrial than domestic waste loading.

Shown in Table 13 are the present and projected waste loads generated for the minor areas. Total organic waste loadings are projected to increase by a factor of almost four by 2020. Within individual minor areas, increases range from fivefold in Q-2, R-1 and R-2, down to three and one-half in Q-4, R-3, and R-5.

Water Quality Control Problems

Listed in Table 14 are the more critical areas and the approximate beginning date of the need for stream regulation for quality control or other appropriate measures for quality control. Secondary treatment or equivalent reduction of wastes is assumed in all cases prior to discharge to the stream.

Water quality control problems exist on many of the major and minor streams in the basin from present organic waste loading remaining after treatment.

TABLE 14

WABASH RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity[1]	Economic Area	Approximate Beginning Date Present	1980	2000	2020
West Fork White River						
Main Stem	Winchester	Q-4	X			
" "	Muncie	Q-4	X			
" "	Anderson	Q-4	X			
" "	Indianapolis	Q-3	X			
Fall Creek	Lawrence	Q-3	X			
" "	Ft. Benjamin Harrison	Q-3	X			
Lick Creek	Beech Grove	Q-3	X			
Eagle Creek	Speedway	Q-3	X			
Duck Creek	Elwood	Q-4	X			
Cicero Creek	Tipton	R-4	X			
Pleasant Run	Greenwood	Q-3	X			
Eel River-Big Walnut Fork	Greencastle	Q-1	X			
Eel River-Birch Creek	Brazil	Q-1	X			
Hawkins Creek	Washington	Q-1	X			
East Fork White River						
Blue River	New Castle	Q-4	X			
" "	Shelbyville	Q-3		X		
Brandywine Creek	Greenfield	Q-3	X			
Flatrock Creek	Rushville	Q-2	X			
Young's Creek	Franklin	Q-3	X			
Main Stem	Columbus	Q-2		X		
Sand Creek	Greensburg	Q-2	X			
Vernon Fork	North Vernon	Q-2	X			
Stuckers Fork	Scottsburg	Q-2	X			
" "	Austin	Q-2	X			
Salt Creek	Oolitic	Q-2	X			
Clear Creek	Bloomington	Q-2	X			
Wabash River						
Main Stem	Bluffton	R-6	X			
" "	Huntington	R-6	X			
" "	Wabash	R-5	X			
" "	Peru	R-5			X	
Salamonie River	Portland	R-6	X			
Lick Creek	Hartford City	R-6	X			
Mississinewa R.	Marion	R-5	X			
L.Mississinewa R.	Union City	Q-4	X			
Tippecanoe River	Warsaw	R-5	X			
Wildcat Creek	Kokomo	R-5	X			
Prairie Creek	Frankfort	R-4	X			
Salt Fork-Vermilion River	Rantoul [2]	R-3	X			
West Branch-Vermilion River	Champaign-Urbana [2]	R-3	X			
Vermilion River	Danville [2]	R-3	X			
Sugar Creek	Crawfordsville	R-4	X			
Prairie Creek	Lebanon	Q-3	X			
Sugar Creek	Paris [2]	R-2	X			
Lamotte Creek	Robinson [2]	R-2	X			
Kickapoo Creek	Mattoon [2]	R-3	X			
" "	Charleston [2]	R-3	X			
Patoka River	Jasper	Q-1	X			
" "	Huntingburg	Q-1	X			
McCarty Ditch	Princeton	Q-1	X			
L.Wabash River	Effingham [2]	R-1	X			
Fox River	Olney [2]	R-1	X			
Seminary Creek	Flora [2]	R-1	X			
Johnson Creek	Fairfield [2]	R-1	X			

1/ Located in State of Indiana unless otherwise noted.
2/ State of Illinois.

Among the major water quality problem areas is the West Fork of the White River below Indianapolis. Design summer low flows of 105 cfs (not including return flows from Indianapolis) are not capable of assimilating present residual organic waste loads without degradation of the stream. Assuming secondary treatment, total summer flows in the order of 800 cfs at present, 1,100 cfs by 1980, 1,500 cfs by 2000, and 2,000 cfs by 2020 are needed. However, storage for the purpose of regulation of streamflow for water quality control after secondary treatment of the organic constituents of wastes appears to be only a partial solution in the main stem below Indianapolis as the quantity of water required exceeds the average flow of the White River.

Other stream reaches in the drainage area of the West Fork of the White River above Indianapolis, where stream conditions are unsatisfactory, include the reaches of the main stem below Winchester, Muncie and Anderson and the tributary streams of Cicero Creek below Tipton and Duck Creek below Elwood. Design flow in the main stem below Winchester is very low and flows in the order of 7 cfs are needed at the present, increasing to 10 cfs by 1980, to 15 cfs by 2000, and to 20 cfs by 2020. At Muncie, design flow is in the order of 2 cfs and total summer flows in the order of 55 cfs are needed at the present, increasing to 75 cfs by 1980, to 100 cfs by 2000, and to 125 cfs by 2020. Design flow at Anderson is about 36 cfs and summer flows in the order of 60 cfs are needed at present, increasing to 85 cfs by 1980, to 150 cfs by 2000, and to 300 cfs by 2020, providing that the flow regulation is added above Muncie thus decreasing travel time from Muncie to Anderson. Since storage above Muncie in the quantity required does not appear to be available, intensive treatment is indicated. If flows are not supplied above Muncie, total flows below Anderson in the order of 60 cfs are needed at present, increasing to 85 cfs by 1980, to 110 cfs by 2000, and to 140 cfs by 2020.

In Cicero Creek below Tipton, there is often no flow in the summer months. Flow in the order of 10 cfs is needed at the present, increasing to 15 cfs by 1980, to 18 cfs by 2000, and to 22 cfs by 2020. In Duck Creek below Elwood, summer flows are very low and flows in the order of 12 cfs are needed at present, increasing to 20 cfs by 1980, to 25 cfs by 2000, and to 30 cfs by 2020. In the tributary basins, it is doubtful whether storage is available and intensive treatment and holding or "polishing" ponds will probably be required from which effluent can be released during periods of higher flows.

In the West Fork White River drainage area below Indianapolis, stream conditions are unsatisfactory in the tributary streams of Pleasant Run below Greenwood, Big Walnut Creek below Greencastle, Birch Creek below Brazil and Hawkins Creek below Washington. Design flow in Pleasant Run, Birch Creek, and Hawkins Creek is very low and in Big Walnut Creek the design flow is about 4 cfs. In Pleasant Run and Big Walnut Creek, flows in the order of 10 cfs are needed at the present, increasing to 20 cfs by 1980, 25 cfs by 2000, and 40 cfs by 2020. In Birch Creek and Hawkins Creek, flows in the order of 12 cfs are needed at present, increasing to 22 cfs by 1980, 33 cfs by 2000, and 45 cfs by 2020. Storage for purpose of streamflow regulation does not appear to be available above these communities and intensive treatment of wastes is indicated. An alternate solution in the Washington area is discharge of wastes remaining after treatment to a larger body of receiving water, the West Fork of the White River.

In the East Fork White River subbasin, conditions are unsatisfactory at present in the Blue River below New Castle where design flows of about 15 cfs are not sufficient to assimilate residual organics discharged to the stream. Flows in the order of 25 cfs are needed at present, increasing to 35 cfs by 1980, 50 cfs by 2000, and 65 cfs by 2020. Further downstream at Shelbyville, design flows in the order of 37 cfs will be sufficient until about 1980 to assimilate wastes after secondary treatment. After 1980, 50 cfs will be needed, increasing to 125 cfs by 2000 and to about 300 cfs by 2020. Provision of the aforementioned flows at Shelbyville anticipates the discharge of treated wastes from a future treatment plant serving eastern Marion County.

Stream conditions are unsatisfactory at the present in Brandywine Creek below Greenfield, Flatrock Creek below Rushville, Young's Creek below Franklin, Sand Creek below Greensburg and Salt Creek below Oolitic. The design flows in these streams are very low. Flows in the order of 12 to 15 cfs are needed at present, increasing to 20 cfs by 1980, 30 cfs by 2000, and 35 or 40 cfs by 2020. Storage potential in the watersheds above these communities does not appear to be sufficient to meet these needs and intensive treatment is indicated.

Columbus, Indiana, is located where the Driftwood River and Flatrock Creek combine to form the East Fork White River. Provided sewage receives adequate treatment, the design flow of 76 cfs should be sufficient to assimilate residual organic wastes until 1980. However, by 2000, total flow in the order of 135 cfs will be needed and by 2020 flow needs will increase to 170 cfs.

In the Muscatatuck River subbasin, flow regulation is needed at the present below North Vernon in Vernon Fork and below Austin and Scottsburg in Stuckers Fork. The design flow in these streams is very low. In order to maintain satisfactory stream conditions, summer flows in both streams in the order of 7 cfs are needed at the present, increasing to 12 cfs by 1980, 18 cfs by 2000, and 25 cfs by 2020. If these flows are furnished in Stuckers Fork at Scottsburg, the needs will also be met at Austin. As these communities are located in the headwater reaches of the streams, storage in the quantity required does not appear to be available. Intensive treatment is indicated in connection with holding or "polishing" ponds where sewage plant effluent can be stored and released during periods of higher flows.

Bloomington is located in the headwaters region of tributaries draining to the East and West Forks of the White River. Effluent from the treatment plant is discharged into the West Fork drainage area by way of Clear Creek, a tributary of Salt Creek. Conditions in Clear Creek are unsatisfactory at present where there is very little low flow. Flows in the order of 25 cfs are needed at the present, increasing to 45 cfs in 1980, 60 cfs by 2000, and 80 cfs by 2020. Clear Creek joins Salt Creek below the Monroe Reservoir and planned releases from this reservoir would maintain satisfactory conditions in Salt Creek even if the sewage plant effluent would be discharged directly into Salt Creek, and the unsatisfactory conditions in Clear Creek would, therefore, be corrected.

In the upper Wabash River drainage area, unsatisfactory conditions exist at the present in the Wabash River below Bluffton, Huntington and Wabash, Indiana. Design flow in the stream varies from 5 cfs below Bluffton, to 9 cfs below Huntington, and to 26 cfs below Wabash. At Bluffton, flows in the order of 15 cfs are needed at the present, increasing to 20 cfs by 1980, 25 cfs by 2000, and 35 cfs by 2020. At Huntington,

assuming treated wastes are discharged to the Wabash River, flows in the order of 30 cfs are needed at present, increasing to 35 cfs by 1980, 50 cfs by 2000, and 70 cfs by 2020. These flows could probably be made available by reallocation of storage in the Huntington Reservoir now under construction on the Wabash River above Huntington. At Wabash, flows in the order of 30 cfs are needed at the present to assimilate adequately treated wastes, increasing to 36 cfs by 1980, 50 cfs by 2000, and 70 cfs by 2020. Planned releases from the Federal multipurpose reservoir now under construction on the Salamonie River will supply the needed flow. At Peru by 2000, total flows in the order of 95 cfs will be needed, increasing to 125 cfs by 2020 in order to maintain satisfactory stream conditions. Planned releases from the previously mentioned Salamonie Reservoir and from a Federal reservoir under construction on the Mississinewa Reservoir will supply not only these needs but will maintain satisfactory stream conditions in the entire length of the Wabash River from Peru to its mouth.

In the Salamonie River drainage basin, unsatisfactory stream conditions presently exist in the main stem below Portland where design flow in the stream is less than 5 cfs. Flows in the order of 8 cfs are needed at present, increasing to 15 cfs by 1980, 20 cfs by 2000, and 25 cfs by 2020. Storage does not appear to be available above Portland since it is in the headwater region and intensive treatment along with holding ponds for storage and release during periods of higher flows appears to be indicated.

In the Mississinewa River Basin at present, stream conditions are unsatisfactory in Lick Creek below Hartford City where the design flow is zero, the the Little Mississinewa River below Union City where the design flow is zero, and in the main stem below Marion where the design flow is 16 cfs. In Lick Creek below Hartford City and in the Little Mississinewa River below Union City, flows in the order of 10 cfs are needed at the present, increasing to 13 cfs by 1980, to 17 cfs by 2000, and to 25 cfs by 2020. In the main stem below Marion, flows in the order of 45 cfs are needed at the present, increasing to 65 cfs by 1980, to 80 cfs by 2000, and to 110 cfs by 2020. If storage is made available to meet these needs at Marion, a solution to

the problem at Hartford City could be to discharge adequate treated effluent to the Mississinewa River below a future reservoir constructed to regulate flows at Marion. In the event that such a reservoir is not constructed, intensive treatment is indicated at both locations. Since Union City is in the extreme headwater region, intensive treatment is indicated.

Stream conditions are unsatisfactory at present in the Tippecanoe River below Warsaw where the design flow is 3 cfs. Flows in the order of 10 cfs are needed at the present, increasing to 15 cfs by 1980, to 20 cfs by 2000 and to 25 cfs by 2020. Since storage does not appear to be available above Warsaw, intensive treatment is indicated.

In the Wildcat Creek drainage basin, the principal problem area is Wildcat Creek below Kokomo where the design flow is 4 cfs. Flows in the order of 45 cfs are needed at present, increasing to 60 cfs by 1980, to 80 cfs by 2000, and to 100 cfs by 2020. Another problem exists at the present on Prairie Creek, below Frankfort a tributary of the South Branch of Wildcat Creek, where there is no low summer flow. Flows in the order of 20 cfs are needed at the present, increasing to 28 cfs by 1980, 35 cfs by 2000, and 50 cfs by 2020. Storage does not appear to be available above either of these communities and intensive treatment appears to be indicated.

In the Vermilion River subbasin in Illinois, unsatisfactory stream conditions exist at the present in the Salt Fork below Rantoul, the West Branch below Champaign-Urbana and in the main stem below Danville. Design flow in Salt Fork and West Branch of the Salt Fork is less than 5 cfs and in the Vermilion River below Danville 14 cfs. Flows in the order of 15 cfs are needed at the present in Salt Fork below Rantoul, increasing to 25 cfs by 1980, to 35 cfs by 2000, and to 45 cfs by 2020. At Champaign-Urbana in the West Branch at the present, flows in the order of 50 cfs are needed, increasing to 75 cfs by 1980, to 105 cfs by 2000, and to 125 cfs by 2020. Since both of these communities are located in the headwater region of the Vermilion River Basin, storage to furnish these flows does not appear to be available and intensive treatment and holding ponds appear to be indicated. At Danville, flows in the order of 80 cfs are needed at the present, increasing to 115 cfs by 1980, to 160 cfs by 2000, and to 210 cfs by 2020.

In Sugar Creek in Indiana, unsatisfactory stream conditions exist at present below Crawfordsville on the main stem and on Prairie Creek below Lebanon. In Sugar Creek below Crawfordsville, design flow is about 5 cfs. Flows in the order of 15 cfs are needed at the present, increasing to 30 cfs by 1980, to 45 cfs by 2000, and to 60 cfs by 2020. In Prairie Creek below Lebanon, design flow is zero. Flows in the order described above for Sugar Creek are needed below Lebanon. However, Lebanon is in the headwater region and storage probably cannot be made available. Therefore, intensive treatment is indicated including holding or "polishing" ponds for storage of effluent and release during periods of higher flow.

In Sugar Creek in Illinois below Paris, there is probably no streamflow during the summer months. Flows in the order of 10 cfs are needed at present, increasing to 15 cfs by 1980, to 22 cfs by 2000, and to 30 cfs by 2020. Since Paris is in the headwater region, storage to sustain these flows is not available and intensive treatment is indicated.

Stream conditions in Lamotte Creek below Robinson, Illinois, are unsatisfactory during low flow periods. Flows in the order of 10 cfs are needed at the present to maintain satisfactory stream conditions and the needs are estimated to increase to 18 cfs by 1980, to 25 cfs by 2000, and to 30 cfs by 2020. Since storage does not appear to be available above this headwater community, intensive treatment is indicated.

In the Embarrass River subbasin in Illinois, unsatisfactory stream conditions exist in Kickapoo Creek below Mattoon and Charleston where summer flows are very low. At Mattoon, flows in the order of 20 cfs are needed at the present, increasing to 35 cfs by 1980, to 45 cfs by 2000, and to 55 cfs by 2020. At Charleston, flows in the order of 12 cfs are needed at present, increasing to 20 cfs by 1980, to 25 cfs by 2000, and to 30 cfs by 2020. If the flows could be supplied at Mattoon, stream conditions would be satisfactory at Charleston. However, since these are headwater communities it does not appear that storage of the magnitude required can be developed and intensive treatment is indicated. If storage were developed in the Embarrass River above Charleston, an alternate to the problem at Charleston could be discharge of the treated wastes into the regulated Embarrass River.

In the Patoka River Basin, stream conditions below Jasper and Huntingburg are unsatisfactory at the present since design flow is zero in this reach. Flows in the order of 7 cfs are needed below Jasper at the present, increasing to 32 cfs by 1980, to 50 cfs by 2000, and to 66 cfs by 2020. Below Huntingburg total flows needed are 7 cfs at the present, increasing to 32 cfs by 1980, to 50 cfs by 2000, and to 66 cfs by 2020. Princeton, also located in the Patoka River Basin, presently discharges sewage treatment plant effluent into McCarthy Ditch to the Wabash River. Flows in the order of 11 cfs are needed at the present, increasing to 15 cfs by 1980, to 26 cfs by 2000, and to 30 cfs by 2020. Storage cannot be made available to furnish these flows and intensive treatment is indicated. An alternative for Princeton could be disposal of treated effluent to the Patoka River, if the flows are furnished to meet the needs at Jasper and Huntingburg upstream.

In the Little Wabash River Basin, stream conditions are unsatisfactory in the Little Wabash River below Effingham, the Fox River below Olney, Seminary Creek below Flora, and Johnson Creek below Fairfield. Design flow is very low at all these points. In the Little Wabash River below Effingham, flows in the order of 10 cfs are needed at the present, increasing to 17 cfs by 1980, to 24 cfs by 2000, and to 35 cfs by 2020. In the Fox River below Olney, Seminary Creek below Flora, and Johnson Creek below Fairfield, flows in the order of 6 cfs are needed at the present, increasing to 10 cfs by 1980, to 15 cfs by 2000, and to 20 cfs by 2020. As all these communities are in the headwater region of the streams, storage for the purpose of streamflow regulation does not appear to be available and intensive treatment in conjunction with holding or "polishing" ponds to release effluent during periods of higher flows seems to be indicated.

There are undoubtedly other small tributaries adversely affected by discharge of residual wastes remaining after secondary treatment, but it is beyond the scope of this report to define them all.

Quality problems unrelated to population are heat, chloride, and acid mine drainage. Along the West Fork of the White River are located thermal power generating plants with installed capacities of 10 megawatts (MW) at Anderson, 100 MW at Noblesville, plants with 372.6 MW, 47.5 MW, 10 MW, and 6.8 MW capacities at Indianapolis, and plants with capacities of 393.6 MW at Centerton, 159 MW at Edwardsport, and 18 MW at Washington. A plant with 220 MW installed capacity is scheduled to begin operation at Petersburg in 1967.

Along the main stem of the Wabash River are located plants with installed capacities of 12.5 MW at Celina, Ohio, 7 MW at Bluffton, 40 MW at Peru, 52 MW at Logansport, 210 MW and 6 MW at Terre Haute, 575 MW at West Terre Haute, Indiana, and 450 MW at Sullivan, 212.5 MW at Hutsonville and 20.5 MW at Mount Carmel, Illinois.

In addition, scheduled for operation in 1968 is a plant with installed capacity of 318 MW at Terre Haute.

In tributary basins, a plant with an installed capacity of 36.8 MW is located at Frankfort, Indiana, in the Wildcat Creek subbasin, and a plant with a capacity of 40 MW is located at Crawfordsville, Indiana, in the Sugar Creek subbasin.

In Illinois in the Vermilion River subbasin, a plant with a capacity of 8 MW is located at Rantoul, a plant with a capacity of 182.3 MW is located at Oakwood, and a plant with a capacity of 7.5 MW is located at Danville. At Marshall in the Mill Creek subbasin is located a plant with a capacity of 5.6 MW. In the Embarrass River subbasin, plants are located at Robinson, Champaign, and Tuscola with capacities of 12, 30, and 12.5 MW respectively. In the Little Wabash River subbasin, plants are located at Fairfield and Carmi with capacities of 12.5 and 10.2 MW respectively. Thermal pollution is not presently a major problem. However, with the possible advent of large mine mouth power plants in the coal producing areas of the basin, some such problems may arise.

Chloride problems from oil field brines exist in the lower reaches of the Embarrass and Patoka River Basins and in scattered areas in the Little Wabash Basin as well as in Bonpas Creek in Illinois and Big Creek in Indiana. Control of such pollution appears to be largely one of control at the source with injection of brines into deep disposal wells.

Acid mine drainage is a major problem in the Patoka River Basin. Such pollution was largely responsible for Princeton, Indiana, going to a well source of supply. Other areas where acid mine drainage is a problem include Busseron and Birch Creeks in Indiana and Sugar Creek in Illinois. Solution of these problems will probably require a combination of control at the source measures along with flow regulation.

TABLES

TABLE 1

WABASH RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Indiana		Adams	27.7
"		Allen	24.5
"	*	Bartholomew	100.0
"	*	Benton	64.8
"	*	Blackford	100.0
"	*	Boone	100.0
"	*	Brown	100.0
"	*	Carroll	100.0
"	*	Cass	100.0
Illinois	*	Champaign	60.7
"	*	Clark	100.0
Indiana		Clark	0.4
Illinois	*	Clay	100.0
Indiana	*	Clay	100.0
"	*	Clinton	100.0
Illinois	*	Coles	80.8
"	*	Crawford	100.0
Indiana		Crawford	18.9
Illinois	*	Cumberland	100.0
Ohio		Darke	10.3
Indiana	*	Daviess	100.0

TABLE 1 (cont'd)

WABASH RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Indiana	*	Decatur	89.4
"	*	Delaware	100.0
Illinois	*	Douglas	67.7
Indiana	*	Dubois	88.4
Illinois	*	Edgar	100.0
"	*	Edwards	100.0
"	*	Effingham	90.7
"		Fayette	4.9
Indiana		Fayette	8.0
Illinois		Ford	30.2
Indiana	*	Fountain	100.0
"	*	Fulton	100.0
Illinois		Gallatin	11.9
Indiana	*	Gibson	70.8
"	*	Grant	100.0
"	*	Greene	100.0
Illinois	*	Hamilton	42.4
Indiana	*	Hamilton	100.0
"	*	Hancock	100.0
"	*	Hendricks	100.0
"	*	Henry	93.7

TABLE 1 (cont'd)

WABASH RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Indiana	*	Howard	100.0
"	*	Huntington	100.0
Illinois		Iroquois	2.4
Indiana	*	Jackson	100.0
Illinois	*	Jasper	100.0
Indiana	*	Jay	100.0
Illinois		Jefferson	16.9
Indiana		Jefferson	50.8
"	*	Jennings	100.0
"	*	Johnson	100.0
"	*	Knox	100.0
"	*	Kosciusko	73.5
Illinois	*	Lawrence	100.0
Indiana	*	Lawrence	100.0
Illinois		Livingston	1.2
Indiana	*	Madison	100.0
Illinois		Marion	36.8
Indiana	*	Marion	100.0
"		Marshall	29.3
"	*	Martin	100.0
Ohio		Mercer	46.4

TABLE 1 (cont'd)

WABASH RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Indiana	*	Miami	100.0
"	*	Monroe	100.0
"	*	Montgomery	100.0
"	*	Morgan	100.0
"		Noble	11.5
"	*	Orange	97.2
"	*	Owen	100.0
"	*	Parke	100.0
"	*	Pike	97.7
"		Posey	74.6
"	*	Pulaski	81.5
"	*	Putnam	100.0
"	*	Randolph	73.5
Illinois	*	Richland	100.0
Indiana		Ripley	33.9
"	*	Rush	96.3
"	*	Scott	91.8
Illinois		Shelby	14.7
Indiana	*	Shelby	100.0
"		Spencer	2.0
"		Starke	15.6

TABLE 1 (cont'd)

WABASH RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Indiana	*	Sullivan	100.0
"	*	Tippecanoe	100.0
"	*	Tipton	100.0
"		Vanderburgh	28.1
Illinois	*	Vermilion	93.7
Indiana	*	Vermillion	100.0
"	*	Vigo	100.0
Illinois	*	Wabash	100.0
Indiana	*	Wabash	100.0
"	*	Warren	100.0
"		Warrick	3.4
"	*	Washington	45.4
Illinois	*	Wayne	100.0
Indiana	*	Wells	97.0
Illinois	*	White	88.1
Indiana	*	White	83.2
"	*	Whitley	100.0

*Counties considered in economic projections of Wabash River Basin.

TABLE 2

WABASH RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from Confluence with Ohio River
Wabash River	33,100	475	0
Little Wabash River	3,380	200	15
Patoka River	850	138	95
White River	11,290 1/	52	96
East Fork	5,680	282	147
West Fork	5,430	255	147
Embarrass River	2,350	185	122
Sugar Creek	840	72	245
Vermilion River	1,520	68	257
Wildcat Creek	800	81	317
Tippecanoe River	1,920	166	322
Eel River	850	100	354
Mississinewa River	820	100	375

1/ Includes East and West Fork.

TABLE 3

WABASH RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Indianapolis	Marion	Indiana	233,650	314,194	364,161	386,972	427,173	476,258
Terre Haute	Vigo	"	58,157	66,083	62,810	62,693	64,214	72,500
Muncie	Delaware	"	24,005	36,524	46,548	49,720	58,479	68,603
Champaign	Champaign	Illinois	12,421	15,873	20,348	23,302	39,563	49,583
Anderson	Madison	Indiana	22,476	29,767	39,804	41,572	46,820	49,061
Kokomo	Howard	"	17,010	30,067	32,843	33,795	38,672	47,197
LaFayette	Tippecanoe	"	20,081	22,486	26,240	28,798	35,568	42,330
Danville	Vermilion	Illinois	27,871	33,776	36,765	36,919	37,864	41,856
Marion	Grant	Indiana	19,359	23,747	24,496	26,767	30,081	37,854
Bloomington	Monroe	"	8,838	11,595	18,227	20,870	28,163	31,357
Urbana	Champaign	Illinois	8,245	10,244	13,060	14,064	22,834	27,294
Rantoul	"	"	1,384	1,551	1,555	2,367	6,387	22,116
Logansport	Cass	Indiana	19,050	21,626	18,508	20,177	21,031	21,106
Columbus	Bartholomew	"	8,813	8,990	9,935	11,738	18,370	20,778
New Castle	Henry	"	9,446	14,458	14,027	16,620	18,271	20,349
Mattoon	Coles	Illinois	11,456	13,552	14,631	15,827	17,547	19,088
Vincennes	Knox	Indiana	14,895	17,160	17,564	18,228	18,831	18,046
Huntington	Huntington	"	10,272	14,000	13,420	13,903	15,079	16,185
Frankfort	Clinton	"	8,634	11,585	12,196	13,706	15,028	15,302
Peru	Miami	"	10,910	12,410	12,730	12,432	13,308	14,453
Shelbyville	Shelby	"	9,500	9,701	10,618	10,791	11,734	14,317
Crawfordsville	Montgomery	"	9,371	10,139	10,335	11,089	12,851	14,231
Bedford	Lawrence	"	8,716	9,076	13,208	12,514	12,562	13,024
West Lafayette	Tippecanoe	"	3,867	3,830	5,095	6,270	11,873	12,680
Wabash	Wabash	"	8,687	9,872	8,840	9,653	10,621	12,621
Elwood	Madison	"	11,028	10,790	10,685	10,913	11,362	11,793
Seymour	Jackson	"	6,305	7,348	7,508	8,620	9,629	11,629
Beech Grove 1/	Marion	"	568	1,459	3,552	3,907	5,685	10,973
Washington	Daviess	"	7,854	8,743	9,070	9,312	10,987	10,846
Charleston	Coles	Illinois	5,884	6,615	8,012	8,197	9,164	10,505
Lawrence 1/	Marion	Indiana	-	-	840	1,087	1,951	10,103

1/ Part of Indianapolis, Indiana urbanized area.

TABLE 4

WABASH RIVER BASIN

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Normal Pool Area (acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Grand Lake	R	12,800			90,000
Salamonie Res. 2/	F, A, R	2,860 1/	250,500		47,600
Mississinewa Res. 2/	F, A, R	3,180 1/	345,100		51,900
Huntington Res. 2/	F, R	900 1/	149,000		
Monroe Res.	F, W, R	10,750 1/	258,800		159,900
Lake Shafer	P, R	14,040			
Eagle Creek Res. 2/	F, R	1,350	42,400		24,000
Brush Creek	W	185			
Lake Freeman	P				
Bradford Woods Lake	R	110			1,200
Cagles Mill Res.	F, R	1,400 1/	201,000		
Glendale	R	1,313			20,400
Mansfield Res.	F, A, R	2,060 1/	116,600		33,100
Holiday Lake	R	168			2,435
Geist Res.	W	1,900		21,500	
Huntingburg City Lake	W, R	180		2,000	
Morse Res.	W	1,375		21,500	
Lamb Indian Creek	R	309			7,250
Prairie Crk. Res.	W			21,500	
Lake Vermilion	W, R	7,960			
Princess East Lake	R, W	7,000			
Kickapoo Lakes	R				
Springs Valley	R, F	141			1,687
Twin Lakes	R				
Lake Charleston	R	358		2,100	
Lake Mattoon	W, R	1,136		12,000	
Lake Paradise		176		4,500	
Norris Co. Res.	W, R				
Turkey Run Lake	R				
Lake Lemon-Bean	W			16,800	
Lake Griffey	W	100			
Lake Greenwood	W			8,000	
Vermillion Fishing Club	R	105			
Lincoln Trail State Park	R	158			
New City Lake	R	176			
Omega Lake	R	585			
Olney New Lake	W	137			
Mesa Lake	R	125			
Lake Johnsonville	R	194			
Lake Sara	W, R	586		13,800	
Grandview Lake	R	324			
Beaver Lake	W				
Lake Salinda	W				
Starve Hollow Lake	R				

1/ Seasonal Pool
2/ Under Construction

F - Flood Control
A - Low Flow Regulation
R - Recreation
W - Water Supply
P - Power

TABLE 5

WABASH RIVER BASIN

Flow Data 3/

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Wabash River						
Bluffton, Indiana	506	403	3.9	11,800	4.7	3
Huntington, Indiana	710	663	4.3	19,800	9	
Wabash, Indiana	1,733	1,511	17	49,600	26	13
Peru, Indiana	2,655	2,532	62	68,000	87	
Logansport, Indiana	3,751	3,717	97	89,800	190	128
Delphi, Indiana	4,032	3,539	158	85,300	204	
Lafayette, Indiana	7,247	6,401	265	131,000	535	392
Covington, Indiana	8,208	7,245	487	147,000	630	
Montezuma, Indiana	11,100	9,492	510	184,000	775	578
Terre Haute, Indiana	12,200	10,440	690	189,000	900	654
Riverton, Indiana	13,100	11,442	858	201,000	1,040	
Vincennes, Indiana	13,700	11,550	770	189,000	1,060	849
Mount Carmel, Illinois	28,600	26,980	1620	305,000	2,250	1,641
White River						
Muncie, Indiana	242	223 1/	0.6	11,500	1.6	
Anderson, Indiana	401	382	8.8	17,100	36	
Noblesville, Indiana	837	821	36	27,200	38	40
Indianapolis, Indiana	1,627	1,021	6.8	37,200	105	79

TABLE 5 (cont'd)

WABASH RIVER BASIN

Location	Drainage Area Above (sq.mi.)	Flow Data[3/] Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
White River (cont'd)						
Martinsville, Indiana	2,435	2,437[2/]	135	43,000	125	
Spencer, Indiana	2,980	3,076[2/]	133	59,400	210	152
Newberry, Indiana	4,696	4,642[2/]	193	76,900	291	213
Petersburg, Indiana	11,139	11,630	533	183,000	685	474
East Fork White River						
Columbus, Indiana	1,692	1,981	87	48,700	76	71
Seymour, Indiana	2,333	2,431	84	78,500	155	107
Bedford, Indiana	3,870			68,400	182	
Shoals, Indiana	4,954	3,951	44	160,000	222	99
Little Wabash River						
Clay City, Illinois	1,130	902	0	47,000	0.55	
Carmi, Illinois	3,090	2,587	0.6	39,400	5.2	.4
Skillet Fork						
Wayne City, Illinois	475	400	0	20,000		
Bonpas Creek						
Browns, Illinois	235	232	0	5,490		
Salt Creek						
Peerless, Indiana	582	707	0.7	20,400	0.9	

TABLE 5 (cont'd)

WABASH RIVER BASIN

Flow Data[3/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Embarrass River						
North Fork Embarrass River						
Oblong, Illinois	304	258	0	27,100	.1	
Saint Marie, Illinois	1,540	1,227	1.0	44,800	16	6.1
Sugar Creek						
Crawfordsville, Indiana	509	486	1.8	26,300	5	
Vermillion River						
Salt Fork						
West Branch						
Urbana, Illinois	714	516	1.2	3,410	2.3	
Homer, Illinois	344	254	3.5	6,170	6.8	
Catlin, Illinois	959	725	8.0	36,000	12	
Danville, Illinois	1,280	897	2.0	48,700	14	
Wildcat Creek						
Greentown, Indiana	162	154	0.9	6,320	1.2	
Owasco, Indiana	390	385	10	10,200	15	
South Fork Wildcat Creek						
Near Lafayette, Indiana	246	249	15	12,600	18	
Tippecanoe River						
Delphi, Indiana	1,857	1,601	1.0	22,600	188	

TABLE 5 (cont'd)

WABASH RIVER BASIN

Flow Data[3/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Eel River						
Bowling Green, Indiana	844	854	11	34,000	17	
Mississinewa River						
Ridgeville, Indiana	130	143	0.1	13,900	0.8	
Eaton, Indiana	304	300	2.0	19,400	2.4	
Marion, Indiana	677	650	3.8	25,000	16	
Peoria, Indiana	809	740	26	28,000	33	
Little River						
Huntington, Indiana	266	252	1.0	5,990	2.3	

1/ Adjusted
2/ Unadjusted
3/ Excerpted from "Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey."

TABLE 6

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation Q-1									
Indiana	Clay	24,200	8,900						
"	Daviess	26,600	10,800						
"	Dubois	27,500	10,900						
"	Gibson	29,900	10,900						
"	Greene	26,300	5,700						
"	Knox	41,600	21,900						
"	Owen	11,400	2,600						
"	Pike	12,800	2,900						
"	Putnam	24,900	8,500						
	Subtotal	225,200	83,100	314,000		445,000		620,000	
Area Designation Q-2									
Indiana	Bartholomew	48,200	20,900						
"	Brown	7,000	0						
"	Decatur	20,000	6,600						
"	Jackson	30,600	11,600						
"	Jennings	17,300	4,100						
"	Lawrence	36,600	16,600						
"	Martin	10,600	2,900						
"	Monroe	59,200	31,400						
"	Orange	16,900	2,800						
"	Rush	20,400	7,300						
"	Scott	14,600	7,600						
"	Washington	17,800	4,500						
	Subtotal	299,200	116,300	454,000		665,000		960,000	

TABLE 6 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation Q-3									
Indiana	Boone	27,500	9,500						
"	Hamilton	40,100	11,100						
"	Hancock	26,700	9,000						
"	Hendricks	40,900	13,200						
"	Johnson	43,700	23,700						
"	Marion	697,600	635,900						
"	Morgan	33,900	11,400						
"	Shelby	34,100	14,300						
	Subtotal	944,500	728,100	1,082,500		1,341,000		1,800,000	
Area Designation Q-4									
Indiana	Delaware	110,900	77,500						
"	Henry	48,900	20,300						
"	Madison	125,800	72,800						
"	Randolph	28,400	9,800						
	Subtotal	314,000	180,400	515,600		665,000		720,000	
TOTAL Subarea Q		1,782,900	1,107,900	2,366,100	1,725,000	3,116,000	2,430,000	4,100,000	3,330,000

TABLE 6 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation R-1									
Illinois	Clay	15,800	5,300						
"	Cumberland	9,900	0						
"	Edwards	7,900	0						
"	Effingham	23,100	8,200						
"	Hamilton	10,000	3,000						
"	Jasper	11,300	2,900						
"	Lawrence	18,500	5,500						
"	Richland	16,300	8,800						
"	Wabash	14,000	8,600						
"	Wayne	19,000	6,400						
"	White	19,400	6,200						
	Subtotal	165,200	54,900	270,800		380,000		480,000	
Area Designation R-2									
Illinois	Clark	16,500	6,200						
"	Crawford	20,800	7,200						
"	Edgar	22,600	9,800						
Indiana	Parke	14,800	2,800						
"	Sullivan	21,700	5,000						
"	Vermillion	17,700	5,800						
"	Vigo	108,500	81,400						
	Subtotal	222,600	118,200	258,700		342,000		510,000	

TABLE 6 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation R-3									
Illinois	Champaign	132,400	100,100						
"	Coles	42,900	29,600						
"	Douglas	19,200	3,900						
"	Vermilion	96,200	60,800						
	Subtotal	290,700	194,400	257,500		325,000		480,000	
Area Designation R-4									
Indiana	Benton	11,900	0						
"	Carroll	16,900	2,500						
"	Cass	40,900	21,100						
"	Clinton	30,800	15,300						
"	Fountain	18,700	7,100						
"	Fulton	17,000	4,900						
"	Montgomery	32,100	14,200						
"	Pulaski	12,800	0						
"	Tippecanoe	89,100	55,000						
"	Tipton	15,900	5,600						
"	Warren	8,500	0						
"	White	19,700	4,000						
	Subtotal	314,300	129,700	395,300		518,000		642,000	

TABLE 6 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation R-5									
Indiana	Grant	75,700	48,000						
"	Howard	69,500	47,200						
"	Kosciusko	40,400	7,200						
"	Miami	38,000	14,500						
"	Wabash	32,600	17,000						
"	Whitley	21,000	4,800						
	Subtotal	277,200	138,700	406,200		480,000		488,000	
Area Designation R-6									
Indiana	Blackford	14,800	8,300						
"	Huntington	33,800	16,200						
"	Jay	22,600	9,900						
"	Wells	21,200	6,200						
	Subtotal	92,400	40,600	150,400		190,000		200,000	
TOTAL Subarea R		1,362,400	676,500	1,738,900	1,056,700	2,235,000	1,541,000	2,800,000	2,181,000
GRAND TOTAL Subareas Q and R		3,145,300	1,784,400	4,105,000	2,781,700	5,351,000	3,971,000	6,900,000	5,511,000

TABLE 7

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation Q-1													
Indiana	Clay	8,200	2,700										
"	Daviess	8,700	1,480										
"	Dubois	9,700	3,850										
"	Gibson	10,400	2,690										
"	Greene	8,800	1,630										
"	Knox	14,500	2,730										
"	Owen	3,700	990										
"	Pike	4,100	730										
"	Putnam	8,500	1,700										
	Subtotal	76,600	18,500	396.5	153	159	246	324	217	494	472	274	1000
Area Designation Q-2													
Indiana	Bartholomew	17,900	7,880										
"	Brown	2,300	730										
"	Decatur	7,200	1,790										
"	Jackson	11,400	4,420										
"	Jennings	5,000	1,660										
"	Lawrence	12,000	4,610										
"	Martin	3,300	1,080										
"	Monroe	22,600	5,360										
"	Orange	6,300	1,860										
"	Rush	7,500	2,000										
"	Scott	4,600	1,880										
"	Washington	6,200	1,940										
	Subtotal	106,300	35,210	774.7	160	149	231	155	199	484	220	276	1013

TABLE 7 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation Q-3													
Indiana	Boone	10,200	2,750										
"	Hamilton	15,300	4,710										
"	Hancock	10,200	3,370										
"	Hendricks	15,200	4,430										
"	Johnson	16,100	5,290										
"	Marion	278,400	87,320										
"	Morgan	11,700	3,450										
"	Shelby	13,100	4,440										
	Subtotal	370,200	115,760	3013.5	110	133	224	140	162	442	177	175	840
Area Designation Q-4													
Indiana	Delaware	41,000	16,380										
"	Henry	18,100	8,220										
"	Madison	48,600	23,760										
"	Randolph	10,700	4,170										
	Subtotal	118,400	52,530	1288.4	164	132	214	202	145	342	248	161	540
Total Subarea Q		671,500	222,000	5473.1	132	137	224	174	168	428	230	196	805

TABLE 7 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation R-1													
Illinois	Clay	5,400	820										
"	Cumberland	3,300	960										
"	Edwards	2,800	490										
"	Effingham	7,900	1,420										
"	Hamilton	3,100	550										
"	Jasper	3,700	610										
"	Lawrence	6,100	1,300										
"	Richland	5,800	770										
"	Wabash	5,100	810										
"	Wayne	6,700	1,120										
"	White	6,700	760										
	Subtotal	56,600	9,610	218.0	174	148	224	242	197	468	332	255	959
Area Designation R-2													
Illinois	Clark	5,400	930										
"	Crawford	7,500	2,290										
"	Edgar	8,100	1,380										
Indiana	Parke	4,800	960										
"	Sullivan	7,200	1,350										
"	Vermilion	5,900	1,460										
"	Vigo	38,500	10,040										
	Subtotal	77,400	18,410	484.7	122	135	203	171	189	418	246	261	835

TABLE 7 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation R-3													
Illinois	Champaign	44,100	3,440										
"	Coles	16,100	3,630										
"	Douglas	6,700	1,440										
"	Vermilion	34,700	10,930										
	Subtotal	101,600	19,440	468.9	92	140	223	125	182	451	171	234	868
Area Designation R-4													
Indiana	Benton	4,200	630										
"	Carroll	6,100	1,560										
"	Cass	14,600	3,700										
"	Clinton	11,400	3,310										
"	Fountain	6,500	2,330										
"	Fulton	6,200	1,600										
"	Montgomery	11,900	3,880										
"	Pulaski	4,400	680										
"	Tippecanoe	33,500	7,120										
"	Tipton	5,800	2,010										
"	Warren	2,900	840										
"	White	7,000	1,720										
	Subtotal	114,500	29,380	690.8	126	138	220	165	178	437	220	226	832

TABLE 7 (cont'd)

WABASH RIVER BASIN

Economic Subareas Q and R
Base and Projected Industrial Activity

State	County	1960			1980 Index**			2000 Index**			2020 Index**		
		Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation R-5													
Indiana	Grant	28,400	12,240										
"	Howard	25,100	11,980										
"	Kosciusko	15,800	5,650										
"	Miami	11,500	3,280										
"	Wabash	13,200	5,490										
"	Whitley	8,000	2,880										
	Subtotal	102,000	41,520	1001.1	145	116	204	167	125	377	195	131	680
Area Designation R-6													
Indiana	Blackford	5,600	2,410										
"	Huntington	12,900	4,820										
"	Jay	8,900	3,710										
"	Wells	8,300	2,550										
	Subtotal	35,700	13,490	315.2	153	122	204	180	140	390	231	158	705
Total Subarea R		487,800	131,850	3178.7	132	130	212	172	161	414	223	197	785
GRAND TOTAL Subareas Q and R		1,158,800	353,850	8651.8	132	135	219	172	166	422	227	196	795

*In millions of 1960 dollars.
**1960 = 100

TABLE 8

WABASH RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Indiana	Adams	*	
"	Allen	*	
"	Clark	N-2	Ohio-Louisville
"	Crawford	N-1	Ohio-Louisville
Ohio	Darke	L-2	Little Miami-Miami
Illinois	Fayette	*	
Indiana	Fayette	L-1	Little Miami-Miami
Illinois	Ford	*	
"	Gallatin	O-1	Ohio-Evansville
"	Iroquois	*	
"	Jefferson	*	
Indiana	Jefferson	N-3	Ohio-Louisville
Illinois	Livingston	*	
"	Marion	*	
Indiana	Marshall	*	
Ohio	Mercer	*	
Indiana	Noble	*	
"	Posey	O-1	Ohio-Evansville
"	Ripley	K-1	Ohio-Cincinnati
Illinois	Shelby	*	
Indiana	Spencer	O-3	Ohio-Evansville
"	Starke	*	
"	Vanderburgh	O-2	Ohio-Evansville
"	Warrick	O-3	Ohio-Evansville

*Not included in Projective Economic Study of Ohio River Basin.

TABLE 9

WABASH RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation Q-1											
Indiana	Clay	3	11,910	11,910		1.070	1.070		90	Wells	.1
"	Daviess	4	15,950	2,950	13,000	1.546	1.546		97	Wells	0
"	Dubois	3	14,900		14,900	1.587		1.587	107	Patoka River, Impoundments	0
"	Gibson	6	15,735	12,100	3,635	1.358	1.120	.238	86	Impoundments, Wells	.2
"	Greene	5	15,400	15,400		1.032	1.032		67	Wells	.2
"	Knox	7	32,060	32,060		3.402	3.402		106	Wells	2.7
"	Owen	2	3,850	3,850		.210	.210		55	Wells	.2
"	Pike	2	5,500		5,500	.430		.430	78	White River, Patoka River	0
"	Putnam	5	11,635	11,635		1.390	1.390		119	Wells	4.1
	Subtotal	37	126,940	89,905	37,035	12.025	9.770	2.255	95		7.5
Area Designation Q-2											
Indiana	Bartholomew	2	23,215	23,215		3.580	3.580		154	Wells	.4
"	Brown	2	595		595	.107		.107	180	Impoundments	0
"	Decatur	3	8,400	500	7,900*	1.135	.035	1.100	135	Wells, Flatrock Creek, Sand Creek	0
"	Jackson	4	15,900	4,900	11,000	1.488	.288	1.200	94	E. Fork White River, Wells	1.1
"	Jennings	1	5,500		5,500	1.000		1.000	182	Muscatatuck River	0
"	Lawrence	2	19,245		19,245	3.866		3.866	200	East Fork White River	1.2
"	Martin	3	6,800	4,400	2,400	.397	.205	.192	58	Wells, Impoundments	.8
"	Monroe	2	45,200	1,500	43,700	6.034	.084	5.950	133	Griffy Crk., Bean Blossom Crk, Impoundments	.6
"	Orange	3	9,100		9,100	.884		.884	97	Lick Creek, Lost River, Wells	0
"	Rush	2	8,100	8,100		.777	.777		96	Wells	2.7
"	Scott	2	8,340		8,340	.571		.571	68	Muscatatuck River, Impoundments	6.3
"	Washington	0									0
	Subtotal	26	150,395	42,615	107,780	19.839	4.969	14.870	132		13.1

TABLE 9 (cont'd)

WABASH RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation Q-3											
Indiana	Boone	6	15,330	15,330		1.030	1.030		67	Wells	.4
"	Hamilton	6	14,500	14,500		1.183	1.183		82	Wells	2.9
"	Hancock	3	14,340	14,340		1.370	1.370		96	Wells	0
"	Hendricks	5	15,980	15,980		1.091	1.091		68	Wells	0.1
"	Johnson	7	21,710	21,140	570	2.667	2.587	.080	123	Wells, Impoundments	0
"	Marion	7	628,670	22,700	605,970	78.303	2.723	75.580	124	Geist Res., Morse Res., White R., Fall Crk., Wells	53.0
"	Morgan	6	14,445	14,445		.997	.997		69	Wells	.1
"	Shelby	2	13,300	13,300		1.629	1.629		122	Wells	.4
	Subtotal	42	738,275	131,735	606,540	88.270	12.610	75.660	120		56.9
Area Designation Q-4											
Indiana	Delaware	5	76,710	5,710	71,000	11.834	.334	11.500	154	W.Fk.White River, Buck Crk., Impound., Wells	1.6
"	Henry	6	27,545	27,545		2.300	2.300		84	Wells	0.1
"	Madison	10	92,280	30,280	62,000	11.580	2.550	9.030	126	W. Fk. White River, Wells	0.2
"	Randolph	6	14,750	14,750		1.996	1.996		135	Wells	0.4
	Subtotal	27	211,285	78,285	133,000	27.710	7.180	20.530	131		2.3
Area Designation R-1											
Illinois	Clay	3	7,420		7,420	.590		.590	80	Little Wabash River	.2
"	Cumberland	3	3,615	2,475	1,140	.180	.130	.050	50	Lake Mattoon, Wells	.2
"	Edwards	2	2,935	1,975	960	.190	.150	.040	65	Wells, Crooked Creek	.1
"	Effingham	5	13,625	2,090	11,535	1.295	.150	1.145	95	Little Wabash R., Second Crk., Wells	0
"	Hamilton	0									0
"	Jasper	2	4,750	4,750		.275	.275		58	Wells	0
"	Lawrence	2	10,005	10,005		1.410	1.410		140	Wells	4.0
"	Richland	4	7,220	1,220	6,000	1.055	.055	1.000	146	Fox River, Wells	0
"	Wabash	4	9,770	1,215	8,555	1.385	.075	1.310	142	Wabash River, Wells	0
"	Wayne	3	8,150	610	7,540	.932	.032	.900	114	Wabash R., Skillet Fork Crk., Wells	0
"	White	4	10,425	3,925	6,500	1.190	.440	.750	114	Little Wabash River, Wells	0
	Subtotal	32	77,915	28,265	49,650	8.502	2.717	5.785	109		4.5

TABLE 9 (cont'd)

WABASH RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation R-2											
Illinois	Clark	4	7,800	7,800		1.123	1.123		144	Wells	6.2
"	Crawford	4	11,515	11,515		1.211	1.211		105	Wells	9.7
"	Edgar	6	12,280	2,780	9,500	1.053	.203	.850	86	Sugar Creek, Wells	0.3
Indiana	Parke	5	6,585	6,585		.483	.483		73	Wells	0.1
"	Sullivan	4	13,225	13,225		.821	.821		62	Wells	0.1
"	Vermillion	6	10,090	10,090		.681	.681		68	Wells	11.6
"	Vigo	2	92,500	4,500	88,000	7.715	.215	7.500	83	Wabash River, Wells	17.1
	Subtotal	31	153,995	56,495	97,500	13.087	4.737	8.350	85		45.1
Area Designation R-3											
Illinois	Champaign	14	102,705	102,705		10.332	10.332		100	Wells	0
"	Coles	5	38,180	700	37,480	2.637	.082	2.555	69	L. Paradise, L.Mattoon, L.Charleston, Wells	.9
"	Douglas	5	7,750	7,750		.460	.460		59	Wells	33.1
"	Vermilion	12	77,545	13,865	63,680	9.570	1.370	8.200	123	Vermilion River, Wells	10.9
	Subtotal	36	226,180	125,020	101,160	22.999	12.244	10.755	102		44.9
Area Designation R-4											
Indiana	Benton	5	5,800	5,800		.383	.383		66	Wells	.1
"	Carroll	3	5,345	5,345		.447	.447		84	Wells and Springs	.2
"	Cass	4	28,250	3,250	25,000	3.358	.243	3.115	119	Eel River, Wells	.6
"	Clinton	5	18,985	18,985		2.681	2.681		141	Wells	.3
"	Fountain	5	10,100	10,100		.779	.779		77	Wells	3.6
"	Fulton	3	6,660	6,660		.586	.586		88	Wells	.6
"	Montgomery	9	20,240	20,240		1.749	1.749		86	Wells	.2
"	Pulaski	3	3,995	3,995		.427	.427		107	Wells	.1
"	Tippecanoe	7	65,840	65,840		5.876	5.876		89	Wells	9.1
"	Tipton	3	7,535	7,535		.736	.736		98	Wells	.5
"	Warren	3	2,230	2,230		.146	.146		66	Wells	0
"	White	6	8,800	8,800		.751	.751		85	Wells	0
	Subtotal	56	183,780	158,780	25,000	17.919	14.804	3.115	98		15.3

TABLE 9 (cont'd)

WABASH RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation R-5											
Indiana	Grant	7	48,400	48,400		7.373	7.373		152	Wells	3.9
"	Howard	4	64,300	5,300	59,000	8.390	.265	8.125	130	Wildcat Crk., Impoundments, Wells	13.4
"	Kosciusko	8	13,855	4,355	9,500	1.888	.388	1.500	136	Center Lake, Wells	0.1
"	Miami	3	15,780	15,780		2.252	2.252		143	Wells	.6
"	Wabash	5	20,470	20,470		2.713	2.713		132	Wells	3.5
"	Whitley	3	7,430	7,430		.923	.923		124	Wells	0.2
	Subtotal	30	170,235	101,735	68,500	23.539	13.914	9.625	138		21.7
Area Designation R-6											
Indiana	Blackford	2	9,080	7,255	1,825	1.256	1.090	.166	138	Salamonie River, Wells	1.1
"	Huntington	5	19,400	4,400	15,000	2.521	.421	2.100	130	Wabash River, Wells	.3
"	Jay	4	13,240	13,240		1.283	1.283		97	Wells	.7
"	Wells	2	7,300	7,300		.647	.647		89	Wells	.3
	Subtotal	13	49,020	32,195	16,825	5.707	3.441	2.266	116		2.4
Other Areas in Basin											
Indiana	Adams	1	1,000	1,000		.070	.070		70	Wells	.4
Ohio	Darke	1	1,655	1,655		.175	.175		106	Wells	.7
Indiana	Fayette	1	450	450		.030	.030		67	Wells	.2
Illinois	Ford	3	5,450	5,450		.485	.485		89	Wells	0
"	Gallatin	1	800	800		.040	.040		50	Wells	0
Indiana	Marshall	2	3,300	3,300		.275	.275		84	Wells	0
Ohio	Mercer	4	13,145	5,145	8,000	1.091	.491	.600	83	Grand Lake, Wells	.6
Indiana	Posey	3	3,250	3,250		.242	.242		74	Wells	0
"	Shelby	1	405	405		.028	.028		69	Wells	0
	Subtotal	17	29,455	21,455	8,000	2.436	1.836	.600	83		1.9
	TOTAL	347	2,117,475	866,485	1,250,990	242.033	88.222	153.811	114		215.6

TABLE 10

WABASH RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation Q-1												
From Central Supplies	126,940	95	12.0	208,200	103	21.4	317,000	115	36.4	470,000	128	60.1
Industrial			7.5			15.1			26.7			48.0
Subtotal			19.5			36.5			63.1			108.1
Area Designation Q-2												
From Central Supplies	150,395	132	19.8	269,200	148	39.8	421,000	160	67.3	645,000	165	106.4
Industrial			13.1			24.8			44.8			84.0
Subtotal			32.9			64.6			112.1			190.4
Area Designation Q-3												
From Central Supplies	738,275	120	88.3	1,004,000	134	134.5	1,322,000	145	191.7	1,964,000	152	298.5
Industrial			56.9			101.1			171.7			317.5
Subtotal			145.2			235.6			363.4			616.0
Area Designation Q-4												
From Central Supplies	211,285	131	27.7	407,800	148	60.3	566,000	160	90.5	689,000	165	113.6
Industrial			2.3			3.9			5.6			8.0
Subtotal			30.0			64.2			96.1			121.6

TABLE 10 (cont'd)

WABASH RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation R-1												
From Central Supplies	77,915	109	8.5	157,400	120	18.8	250,000	130	32.5	354,000	142	50.2
Industrial			4.5			8.3			14.9			27.0
Subtotal			13.0			27.1			47.4			77.2
Area Designation R-2												
From Central Supplies	153,995	85	13.1	220,200	96	21.1	331,000	105	34.7	551,000	118	65.0
Industrial			45.1			76.2			137.1			247.0
Subtotal			58.2			97.3			171.8			312.0
Area Designation R-3												
From Central Supplies	226,180	102	23.0	244,000	112	27.3	353,000	125	44.1	584,000	138	80.5
Industrial			44.9			81.7			141.8			248.0
Subtotal			67.9			109.0			185.9			328.5
Area Designation R-4												
om Central Supplies	183,780	98	17.9	284,900	110	31.3	423,000	120	50.7	586,000	131	76.7
istrial			15.3			27.3			47.1			81.0
ubtotal			33.2			58.6			97.8			157.7

TABLE 10 (cont'd)

WABASH RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation R-5												
From Central Supplies	170,235	138	23.6	308,000	150	46.2	410,000	160	65.6	468,000	169	79.0
Industrial			21.7			34.7			54.4			88.0
Subtotal			45.3			80.9			120.0			167.0
Area Designation R-6												
From Central Supplies	49,020	116	5.7	98,000	118	11.5	141,000	140	19.7	166,000	152	25.2
Industrial			2.4			3.9			6.3			10.0
Subtotal			8.1			15.4			26.0			35.2
Other Areas in Basin												
From Central Supplies	29,455	83	2.4	40,400	95	3.8	55,000	105	5.7	73,000	115	8.3
Industrial			1.9			3.0			4.7			8.0
Subtotal			4.3			6.8			10.4			16.3
Wabash River Basin												
From Central Supplies Total	2,117,475	114	242.0	3,242,100	128	416.0	4,589,000	139	638.9	6,550,000	147	963.5
Industrial Total			215.6			380.0			655.1			1166.5
GRAND TOTAL			457.6			796.0			1294.0			2130.0

TABLE 12

WABASH RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation Q-1						
Indiana	Clay	1	8,800	Birch Creek	8,800	9,850
"	Daviess	2	11,380	Hawkins Crk.,W.Fk.White River	11,380	6,160
"	DuBois	4	11,825	Patoka River, Huntley Creek	11,825	13,010
"	Gibson	2	4,135	S.Fk.Patoka River, Black River	4,135	13,620
"	Greene	4	12,010	Buck Crk.,W.Fk.White River, Eel River	12,010	5,320
"	Knox	2	21,875	Wabash River, Indian Creek	21,875	10,800
"	Owen	1	2,550	West Fork White River	2,550	2,790
"	Pike	2	4,080	White River, Patoka River	4,080	2,450
"	Putnam	2	9,420	Big Walnut Crk., Henry Creek	9,420	5,490
	Subtotal	20	86,075		86,075	60,490
Area Designation Q-2						
Indiana	Bartholomew	2	22,230	East Fork White River, Haw Creek	22,230	22,660
"	Brown	1	500	Salt Creek	500	2,170
"	Decatur	1	6,600	Sand Creek	6,600	70
"	Jackson	4	17,210	E.Fk.White River, Vernon Fork	17,210	3,580
"	Jennings	2	4,460	N.Fk.Muscatatuck River	4,460	4,930
"	Lawrence	3	17,710	Leatherwood Crk.,Rock Lick Cr.,Salt Crk.	17,710	1,900
"	Martin	4	6,020	Boggs Crk.,First Crk.,E.Fk.White R.	6,020	2,650
"	Monroe	2	29,720	Clear Crk.,Jack's Defeat Creek	29,720	15,880
"	Orange	4	7,335	Lick Creek, French Lick Creek	7,335	5,790
"	Rush	2	8,260	Big Flat Rock Crk., Big Blue River	8,260	6,820
"	Scott	1	3,860	Stucker Creek	3,860	12,540
"	Washington	1	4,540	West Fork Blue River	4,540	6,870
	Subtotal	27	128,445		128,445	85,680

TABLE 12 (cont'd)

WABASH RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation Q-3						
Indiana	Boone	5	13,825	Prairie Crk., Big Eagle Crk., Sugar Crk.	13,825	10,770
"	Hamilton	6	15,155	W.Fk.White R., Little Cicero & Cool Crks.	15,155	15,770
"	Hancock	3	11,800	Brandywine Crk., Flat Fork Crk.	11,800	11,240
"	Hendricks	4	13,735	Whitelick Crk., W.Fk.Whitelick Crk.	13,735	40
"	Johnson	5	24,345	Youngs Crk., Pleasant Run, Big Blue R.	24,345	20.140
"	Marion	12	513,610	W.Fk.White R., Lick Crk., Falls Crk., Big Eagle Creek	513,610	840,000
"	Morgan	3	12,200	W.Fk.White R., E.Fk.White Lick Crk.	12,200	11,040
"	Shelby	2	15,005	Big Blue River	15,005	1,700
	Subtotal	40	619,675		619,675	910,700
Area Designation Q-4						
Indiana	Delaware	6	74,150	W.Fk.White R., Mississinewa River	74,150	55,740
"	Henry	5	26,410	Big Blue R., Fall Crk., Six Mile Crk.	26,410	20,390
"	Madison	7	87,070	W.Fk.White R., Big Duck & Pipe Crks.	87,070	60,150
"	Randolph	4	11,910	W.Fk.White R., L.Mississinewa River	11,910	11,260
	Subtotal	24	199,540		199,540	147,540

TABLE 12 (cont'd)

WABASH RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation R-1						
Illinois	Clay	3	7,905	Seminary Crk., Little Wabash River	7,905	2,520
"	Cumberland	3	3,345	Embarrass, Little Wabash Rivers, Cottonwood Crk.	3,345	2,990
"	Edwards	1	2,100	Butter Creek	2,100	1,500
"	Effingham	3	10,070	Mud Crk., Little Wabash River	10,070	5,260
"	Hamilton	1	2,500	Branch of N.Fk.of Saline River	2,500	1,520
"	Jasper	1	2,700	Embarrass River	2,700	2,150
"	Lawrence	4	9,835	Embarrass R., Indian & Raccoon Crks.	9,835	4,300
"	Richland	2	8,660	Branch of Fox R., Little Wabash R.	8,660	3,800
"	Wabash	1	8,595	Wabash River	8,595	1,940
"	Wayne	3	8,505	Johnson, Skillet and Deer Creeks	8,505	2,690
"	White	3	5,600	Little Wabash River, Wabash River	5,600	2,610
	Subtotal	25	69,815		69,815	31,280
Area Designation R-2						
Illinois	Clark	2	4,600	Big Crk., N.Fk.Embarrass River	4,600	3,780
"	Crawford	4	9,980	Lamotte Crk., Big Dogwood Crk.	9,980	9,790
"	Edgar	2	13,220	Sugar Crk., N.Fk.Broullet Crk.	13,220	6,220
Indiana	Parke	2	3,980	Williams Crk., Wabash River	3,980	4,570
"	Sullivan	3	7,295	Buck Crk., Morrison Creek	7,295	7,400
"	Vermilion	4	7,800	Wabash River, Dana Ditch	7,800	7,470
"	Vigo	1	70,000	Wabash River	70,000	281,000
	Subtotal	18	116,875		116,875	320,230

TABLE 12 (cont'd)

WABASH RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation R-3						
Illinois	Champaign	3	119,790	W. Fk. Salt Fork, Salt Fork	119,790	16,800
"	Coles	2	29,000	Kickapoo Creek, Town Branch	29,000	13,470
"	Douglas	2	6,110	Scattering Fork, Embarrass River	6,110	10,770
"	Vermilion	7	59,115	Vermilion R., Grape Crk., Ellis Crk.	59,115	48,890
	Subtotal	14	214,015		214,015	89,930
Area Designation R-4						
Indiana	Benton	5	4,790	Mud Pine Crk., Big Pine Crk., Goose Crk.	4,790	2,330
"	Carroll	3	4.800	Deer Creek, Bachelor Creek	4,800	4,280
"	Cass	4	24,245	Wabash R., Deer Crk., Rock Crk.	24,245	10,970
"	Clinton	4	17,615	Prairie Creek	17,615	3,300
"	Fountain	3	8,500	Wabash River, N. Fk. Coal Creek	8,500	22,300
"	Fulton	3	6,515	Mill Crk., Town Lake, Little Mill Crk.	6,515	6,050
"	Montgomery	4	15,730	Sugar Crk., Big Raccoon Crk.	15,730	400
"	Pulaski	3	4,125	Tippecanoe R., Big Monon Crk.	4,125	2,510
"	Tippecanoe	2	70,440	Wabash River	70,440	23,950
"	Tipton	2	6,730	Cicero Creek, Turkey Creek	6,730	5,930
"	Warren	2	2,020	Fall Branch, Dry Branch	2,020	2,600
"	White	5	8,040	Tippecanoe R., Little Monon Crk.	8,040	4,5[illegible]0
	Subtotal	40	173,550		173,550	89,170

TABLE 12 (cont'd)

WABASH RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation R-5						
Indiana	Grant	7	51,495	Mississinewa River, Black Creek	51,495	31,630
"	Howard	2	54,265	Wildcat Creek	54,265	29,360
"	Kosciusko	6	11,840	Walnut Crk.,Winona Lake, Deeds Crk.	11,840	17,150
"	Miami	3	16,545	Wabash R., Turkey Crk., Big Pipe Crk.	16,545	9,690
"	Wabash	4	18,115	Wabash R., Mississinewa R., Eel R.	18,115	80,000
"	Whitley	3	7,400	Blue River, Eel River	7,400	8,200
	Subtotal	25	159,660		159,660	176,030
Area Designation R-6						
Indiana	Blackford	2	9,900	Little Lick Crk., Salamonie Crk.	9,900	7,020
"	Huntington	6	20,285	Little Wabash R., Salamonie R.	20,285	14,380
"	Jay	3	11,700	Salamonie R., Big Lick Crk.,Halfway Crk.	11,700	12,100
"	Wells	2	7,335	Wabash R., Eight Mile Creek	7,335	8,840
	Subtotal	13	49,220		49,220	42,340
Other Areas in Basin						
Indiana	Adams	1	1,050	Limber Lost Creek	1,050	3,500
"	Allen	2	5,300	Lawrence Ditch	5,300	0
"	Fayette	1	380	Ben Davis Creek	380	0
"	Marshall	2	4,020	Tippecanoe River	4,020	600
Ohio	Mercer	3	11,760	Beaver Crk.,Coldwater Crk.,Wabash R.	11,760	6,920
Indiana	Posey	1	360	Wabash River	360	0
	Subtotal	10	22,870		22,870	11,300
	TOTAL	256	1,839,740		1,839,740	1,964,690

*NOT to be interpreted as waste loads to the stream.

TABLE 13

WABASH RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation Q-1				
Domestic and Commercial	86,075	141,000	216,000	318,000
Industrial	60,490	123,000	216,000	388,000
Subtotal	146,565	264,000	432,000	706,000
Area Designation Q-2				
Domestic and Commercial	128,445	222,000	349,000	533,000
Industrial	85,680	163,000	293,000	551,000
Subtotal	214,125	385,000	642,000	1,084,000
Area Designation Q-3				
Domestic and Commercial	619,675	843,000	1,109,000	1,648,000
Industrial	910,700	1,621,000	2,750,000	5,080,000
Subtotal	1,530,375	2,464,000	3,859,000	6,728,000
Area Designation Q-4				
Domestic and Commercial	199,540	384,000	534,000	650,000
Industrial	147,540	255,000	360,000	516,000
Subtotal	347,080	639,000	894,000	1,166,000

TABLE 13 (cont'd)

WABASH RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation R-1				
Domestic and Commercial	69,815	141,000	224,000	317,000
Industrial	31,280	58,200	104,000	190,000
Subtotal	101,095	199,200	328,000	507,000
Area Designation R-2				
Domestic and Commercial	116,875	167,000	251,000	418,000
Industrial	320,230	540,000	972,000	1,753,000
Subtotal	437,105	707,000	1,223,000	2,171,000
Area Designation R-3				
Domestic and Commercial	214,015	232,000	334,000	552,000
Industrial	89,930	164,000	284,000	496,000
Subtotal	303,945	396,000	618,000	1,048,000
Area Designation R-4				
Domestic and Commercial	173,550	268,000	399,000	553,000
Industrial	89,170	160,000	274,000	471,000
Subtotal	262,720	428,000	673,000	1,024,000

TABLE 13 (cont'd)

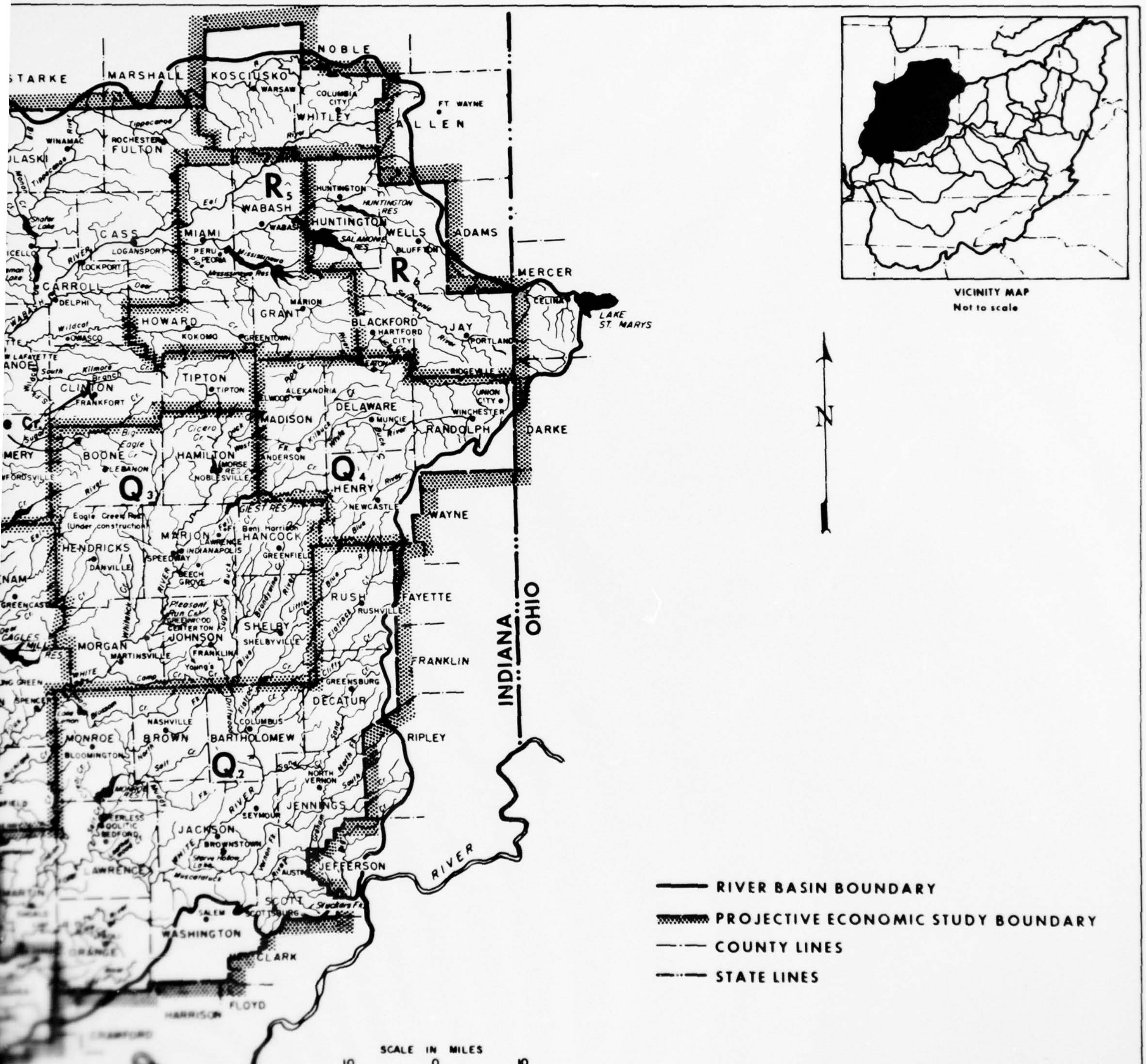
WABASH RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation R-5				
Domestic and Commercial	159,660	289,000	384,000	438,000
Industrial	176,030	282,000	442,000	714,000
Subtotal	335,690	571,000	826,000	1,152,000
Area Designation R-6				
Domestic and Commercial	49,220	98,000	142,000	166,000
Industrial	42,340	69,000	112,000	183,000
Subtotal	91,560	167,000	254,000	349,000
Other Areas in Basin				
Domestic and Commercial	22,870	41,300	55,100	62,900
Industrial	11,300	18,100	28,400	45,800
Subtotal	34,170	59,400	83,500	108,700
Wabash River Basin				
Domestic and Commercial Total	1,839,740	2,826,300	3,997,100	5,655,900
Industrial Total	1,964,690	3,453,300	5,835,400	10,387,800
GRAND TOTAL	3,804,430	6,279,600	9,832,500	16,043,700

*NOT to be interpreted as waste loads to the stream.


ILLINOIS
INDIANA
INDIANA
OHIO
KENTUCKY
SCALE IN MILES
10 0 10
R1
R2
R3
R4
R5
R6
Q1
Q2
Q3
Q4
Prairie Cr.
STARKE
MARSHALL
KOSCIUSKO
NOBLE
WHITLEY
ALLEN
FT WAYNE
NEWTON
JASPER
PULASKI
FULTON
WABASH
HUNTINGTON
WELLS
ADAMS
MIAMI
CASS
WHITE
CARROLL
BENTON
HOWARD
GRANT
BLACKFORD
JAY
MERCER
LIVINGSTON
IROQUOIS
FORD
MC LEAN
WARREN
TIPPECANOE
CLINTON
TIPTON
MADISON
DELAWARE
RANDOLPH
DARKE
CHAMPAIGN
VERMILION
FOUNTAIN
MONTGOMERY
BOONE
HAMILTON
HENRY
WAYNE
PIATT
DOUGLAS
PARKE
HENDRICKS
MARION
HANCOCK
MOULTRIE
EDGAR
VERMILLION
PUTNAM
RUSH
FAYETTE
COLES
VIGO
CLAY
MORGAN
JOHNSON
SHELBY
FRANKLIN
SHELBY
CLARK
CUMBERLAND
OWEN
MONROE
BROWN
BARTHOLOMEW
DECATUR
RIPLEY
EFFINGHAM
JASPER
CRAWFORD
SULLIVAN
GREENE
JACKSON
JENNINGS
FAYETTE
LAWRENCE
KNOX
DAVIESS
MARTIN
JEFFERSON
MARION
CLAY
RICHLAND
SCOTT
WASHINGTON
ORANGE
CLARK
WAYNE
EDWARDS
WABASH
PIKE
DU BOIS
FLOYD
HARRISON
CRAWFORD
JEFFERSON
GIBSON
POSEY
VANDERBURGH
WARRICK
SPENCER
PERRY
HAMILTON
WHITE
FRANKLIN
SALINE
GALLATIN
RIVER
OHIO



OHIO RIVER BASIN FRAMEWORK STUDY

WABASH RIVER BASIN
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

CUMBERLAND RIVER BASIN

Subbasin Area
No. 12

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I SUMMARY

Municipal and Industrial Water Supply Problems

The major location of municipal and industrial water use in the Cumberland River Basin is the Nashville metropolitan area. Due to its location on the Cumberland River, no water supply problems are foreseen during the study period.

Municipal water supply problems will occur in communities on smaller tributaries of the system. A need exists currently for developing a source of supply for Franklin, Tennessee. Additional source development or extension of present facilities will be needed for surface supplies at Murfreesboro, Smithville, Smyrna, and McMinnville, Tennessee by 1980. Surface development could help in meeting projected needs at Springfield, Woodbury, Livingston, and Cookeville, Tennessee by 2000. In the upper and eastern portion of the basin, Monticello, Barbourville, Pineville, Cumberland, and London, Kentucky and Jellico, Tennessee, will need additional source development or extension of present facilities by 2020.

Water Quality Control Problems

The major sources of municipal and industrial wastes are also in the Nashville area. Providing that secondary treatment methods are employed by the city and equivalent waste reduction methods are applied by Davidson County industry, water quality should continue to be acceptable in Cheatham Reservoir below Nashville throughout the study period.

Most of the remaining water quality problems are on local tributaries with short reaches of streams being affected. Areas of larger need are North Fork Little River below Hopkinsville, Kentucky, and in Tennessee, West Fork Stones River below Murfreesboro, West Fork Harpeth River below Franklin, Short Creek below Cookeville, Town Creek below Gallatin, and Sulphur Fork Creek below Springfield. These communities currently have secondary treatment, but being in headwater areas reflect the problems that can occur during drought periods when there is little or no streamflow to assimilate the residual wastes after treatment.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

The Cumberland River is formed by the confluence of Poor and Clover Forks in the Appalachian Plateau region near Harlan, Kentucky. From that point it flows southwesterly into Tennessee and at Nashville turns and flows in a northwesterly direction back into Kentucky. It joins the Ohio River near Smithland, Kentucky, 58 miles above the confluence of the Ohio and Mississippi Rivers and 922 miles below Pittsburgh, Pennsylvania.

The total drainage area of the Cumberland Basin is 17,914 square miles, 7,219 of which lie in southeastern and southwestern Kentucky and 10,695 in north central Tennessee. It is bounded on the south by the Tennessee River Basin and on the north by the Kentucky and Green River Basins. Table 1 lists the 65 counties which lie partially or wholly in the basin.

The main tributaries of the Cumberland River are shown in Table 2 and Figure 12-1, page 12-33.

Physical Features

The topography of the basin varies from rugged mountains in the eastern portion to rolling plateau in the western part. Elevations range from 4,150 feet above sea level in the Cumberland Mountains to 302 feet above sea level at the mouth of the Cumberland River. The upper portion of the basin above Burnside, Kentucky, lies in the Cumberland Mountains of the Appalachian Plateau where the river and its tributaries flow in deep narrow valleys, and have gradients ranging from 10 to 12 feet per mile. In the central portion of the basin between Burnside, Kentucky, and Carthage, Tennessee, the Cumberland River flows through the eastern Highland Rim section of the Interior Low Plateaus where the valleys adjacent to the main stream and tributaries are hilly and the streams have gradients ranging from 3 to 5 feet per mile. Below Carthage, Tennessee, the river flows through the Nashville Basin where the terrain is rolling to hilly. In this region, the main stem and tributaries have gradients of 1 to 3 feet per mile. From near Nashville, Tennessee, to its mouth, the Cumberland River is in the western Highland Rim physiographic section of the Interior Low Plateaus.

Climate

The average annual precipitation in the basin varies from more than 52 inches in the southern part of the basin to about 48 inches at the eastern and western ends. At Nashville, Tennessee, and Williamsburg, Kentucky, the average annual precipitation is between 46 and 47 inches.

Average January temperatures at Nashville and Williamsburg are 39°F and 40°F respectively. The average July temperatures are 80°F and 77°F at the two stations. The average frost-free season is 229 days at Nashville and 184 days at Williamsburg.

Principal Communities and Industries

Listed in Table 3 are some of the principal cities and communities of the basin with their populations from 1910 to 1960.

Agriculture is still a dominant force in the basin's economy. Coal mining is an important industry in the Kentucky counties located in the upper portion of the basin.

Nashville, Tennessee and Davidson County is the economic center of the area and has industrial output in fibers, printing, furniture and flooring, food processing, baking, apparel, phosphates, and tobacco products. Murfreesboro, Tennessee industry produces hosiery, food products, electric motors and heating elements. Hopkinsville, Kentucky industry produces shoes, apparel, lighting fixtures, and stemmed and redried tobacco. Lebanon, Tennessee industry produces luggage, wool products, apparel, auto parts, and accessories.

III WATER RESOURCES

Surface Water Resources

Quantity

Surface flows in the basin are largely controlled by reservoirs. Six major reservoirs currently operate to control flow and three more are under construction. In addition, there are several smaller lakes used primarily for water supply or for recreation. Lake Morris and Lake Boxley, both near Hopkinsville, are examples of this latter type. There is also one small reservoir operated primarily for hydroelectric power.

Lake Barkley, Cheatham Reservoir and Old Hickory Reservoir, on the main stem of the Cumberland River are units in the Corps of Engineers plan for multipurpose development of the river as a unit of the Ohio River system, and provide slack water navigation (9 foot depth) to above Carthage, Tennessee, about 314 miles above the mouth of the river. These reservoirs are also operated for power production, flood control, and recreational uses. Cordell Hull Reservoir under construction will extend navigation to the Kentucky border. Other reservoirs in the multipurpose plan are Dale Hollow on the Obey River, Center Hill on the Caney Fork River and Lake Cumberland on the main stem of the Cumberland River. J. Percy Priest Reservoir will regulate flows from Stones River when it is complete. Great Falls Dam and Lake on the Collins River is operated by TVA for power production. Smaller recreation lakes in Kentucky are Cranks Creek Reservoir in Harlan County and Pine Mountain Lake in Bell County. Table 4 shows pertinent data regarding the aforementioned impoundments.

Flow distribution throughout the year follows a reasonably distinct pattern. Highest streamflows are in the winter months, January through March, and sometimes are extended on into April. Average streamflows then decrease through September and October and begin to increase again late in autumn. There is relatively little storage of ground water in subsurface aquifers, and streamflows tend to reflect precipitation more directly. In the Red River Basin and in various other places, springs make a continuing contribution to flows. These springs are usually fed by complex channel systems in limestone deposits underlying the surface.

Table 5 gives information on streamflows at selected points, excerpted from data prepared by the Corps of Engineers.1/

Quality

Surface waters of the basin are moderately hard, with the main contribution to hardness being of the carbonate type. Typical concentrations of hardness range up to 100 mg/l calcium and magnesium hardness and up to 25 mg/l noncarbonate hardness. During high flows where a large part of the water is from surface runoff, concentrations of dissolved solids are less than during low flows. Total dissolved solids concentrations at Clarksville, Tennessee, are on the order of 100 mg/l during low flow months. Acid mine drainage affects several streams, in both states, where pH values range from 3 to 5 and iron, manganese, and sulfate concentrations are higher than at other basin locations, but the effect on main stem quality is small.

Ground Water Resources

Quantity

Ground water resources are described by the U. S. Geological Survey2/ and the following discussion has been condensed from their report.

This basin has less potential for future ground water development than the other subareas of the Ohio River Basin. Most of the highest yielding sources, the large springs issuing from the Mississippian limestones, are already being used. Yields adequate for small industrial and municipal supplies, however, are available in large areas of the basin.

At depths of 80 to 250 feet in the Mississippian limestones of the western Highland Rim area, yields of 20 to 100 gpm seem to be available almost anywhere in the area. Very few wells extend deeper than 100 feet, and few wells yield over 150 gpm, as does one at Princeton.

Dry weather flow is contributed to the Cumberland River by limestones of the Mississippian system in the eastern Highland Rim area. These limestones and their overburden are often sources of

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1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

2/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

water supply, with many supplies being taken from springs. If a well penetrates a large solution channel in the limestone, it may yield as high as 500 gpm, but a more likely yield is 20 to 100 gpm at a depth of 20 to 50 feet. One spring east of Center Hill Reservoir has a reported flow of 2,600 gpm.

Of somewhat less potential is the ground water supply of the headwater area. This area is underlain by the Pottsville Formation which has an upper half of fine grained sandstone and shale. The lower half has less shale and a coarse grained sandstone through which water can circulate more freely. Shallow wells may yield less than 1 gpm; deeper wells may yield 20 to 100 gpm at depths of 100 to 300 feet.

River alluvium extends along the Cumberland River and its major tributaries for most of their lengths. Virtually no use is made of ground water in the alluvium, either by pumping from wells or infiltration galleries. Basic reasons for this lack of use are frequent inundation of the flood plain and availability of good quality water from the river.

Quality

Ground water from the Mississippian rock system in the western Highland Rim seems to have more hardness and less iron than ground water from the same rock system in the eastern Highland Rim, but the data are not conclusive. Hardness in all but one of the samples analyzed from the western Highland Rim was more than 180 mg/l, while only one analysis showed more than 1 mg/l of iron. The results of many analysis, however, showed iron in greater concentration than the 0.3 mg/l that is considered excessive in drinking water by the U. S. Public Health Service standards.

A few chemical analyses of water from springs and wells in the carbonate rocks of the western Highland Rim indicate that the water ranges in hardness from 50 to 200 mg/l, has negligible amounts of sulfate and chloride, and has less than 400 mg/l of dissolved solids, but is likely to have more than 0.3 mg/l and occasionally as much as 5 mg/l of iron.

Iron content of waters from the Pottsville formation exceeds 0.3 mg/l and is often greater than 3 mg/l. The water normally has less than 120 mg/l of hardness, less than 60 mg/l of sulfate, and less than 20 mg/l of chlorides.

IV THE ECONOMY

The Cumberland subarea of the Projective Economic Study is nearly coextensive with the Cumberland River Drainage Basin, and consists of the eighteen Kentucky counties and twenty-six Tennessee counties listed in Tables 6 and 7 and shown on Figure 12-1, page 12-33. Since future estimates of water requirements and waste loads depend partly upon the hydrology of the area, the subarea has been divided into five minor areas, S-1, S-2, S-3, S-4, and S-5. Minor areas S-1 and S-2 include the lower reaches of the Cumberland River, S-3 the middle reaches, and S-4 and S-5 the upper reaches. Minor areas S-4 and S-5 are entirely within the region designated as Appalachia, and minor area S-3, with the exception of the Tennessee counties of Sumner, Trousdale, Wilson, Rutherford, and Cannon, is also included.

Economic Profiles

Minor Area S-1

The S-1 minor area population was 151,400 in 1960, 30 percent of which was urbanized. Two larger cities, Clarksville, Tennessee, and Hopkinsville, Kentucky, are located in the area, with populations of 22,800 and 19,500 respectively. Average per capita personal income amounted to $1,663, compared to $1,322 for Kentucky and $1,318 for Tennessee.

Agriculture is the most important employment category. Employment fell from 13,600 in 1950 to 8,100 in 1960, and 90,000 acres were taken out of farm production between 1954 and 1959. Even so, the $33.8 million of farm products sold in 1959 represented an increase of five million dollars over the total sold in 1954. Livestock products and field crops each amounted to about 50 percent of the 1959 figure. Seven hundred acres were irrigated in 1959.

Manufacturing establishments employing 100 workers or over are concentrated in Christian and Montgomery Counties. These two counties accounted for 14 of the total 17 plants of this size in the area in 1964. The most important industries are nondurables, furniture and wood products, apparel, and food processing.

The most important mining activity in the area was the extraction of crude oil. In 1960, 1.2 million barrels were produced, nearly all of it in Christian County, Kentucky, representing 5.5 percent of Kentucky's total production for that year.

Minor Area S-2

Total population of minor area S-2 in 1960 was 480,500, 83 percent of which resided in Davidson County Tennessee, which is designated a Standard Metropolitan Statistical Area. Average personal per capita income was $1,771 in Davidson County in 1960 and $1,126 in the remaining area, compared to $1,318 for Tennessee. Nashville with a population of about 171,000 is the major city in the basin as well as in this subarea. The unincorporated communities of Inglewood, Woodmont-Green Hills-Glendale, Donelson, Woodbine-Radner-Glencliff, and Madison are part of the Nashville metropolitan area and total almost 95,000 population.

Manufacturing is the most important employment category and almost wholly confined to Davidson County. Establishments employing 100 workers or over increased from 76 in 1958 to 97 in 1964 in the area, and 90 of these were in Davidson County. The most important industries were printing and allied products, other nondurables, food processing, and other durables. One thermal power plant is located in Davidson County with a generating capacity of 29.5 megawatts. One hydropower generating plant with a capacity of 36 megawatts is located at Cheatham Dam.

Agricultural production increased from a total $24.8 million of farm products sold in 1954 to $32.1 million in 1959. About 55 percent of the latter were composed of livestock products. Six hundred acres were under irrigation.

Mining activity was confined to crushed and broken stone and to sand and gravel extraction. Two phosphate mines were located in the area, one in Davidson County and the other in Williamson County.

Minor Area S-3

Minor area S-3 is the largest minor area in the Cumberland subarea. It is a sparsely settled area with a 1960 population of 267,600 and with two larger cities, Murfreesboro and Lebanon, Tennessee, with populations of 19,000 and 10,500 respectively. Average personal per capita income amounted to $1,016 in 1960.

Manufacturing is characterized by a wide dispersal of plants. Establishments employing 100 workers or over manifested a healthy growth rate between 1958 and 1964, having increased from a total of 40 plants to 56 plants. The major industries are apparel, furniture and wood products, nondurables, and machinery (including electrical machinery). One thermal power plant operated by the Tennessee Valley Authority is located at Gallatin, Tennessee with a capacity of 1,050 megawatts. Three hydropower generating plants operated by the Corps of Engineers are located in this minor area at Dale Hollow, Center Hill and Old Hickory Reservoirs with capacities of 54.0, 135.0 and 100.0 megawatts respectively. The Tennessee Valley Authority operates a hydropower generating plant with a capacity of 31.9 megawatts at Great Falls Lake.1/

Agricultural employment amounted to 20,200 in 1960 equaling 22.3 percent of total employment. The value of farm products sold increased from $44.8 million in 1954 to $63 million in 1959 in spite of the decline in employment between 1950 and 1960 of 16,200. Livestock products accounted for 60 percent of the $63 million value. About 1,000 acres were irrigated.

The most important mining activity in the area is coal extraction. In 1960, 574,600 tons of coal were produced equaling 10 percent of Tennessee's total production.

Minor Area S-4

Minor area S-4 is also a sparsely settled area with a 1960 population of 134,300. The largest city is Somerset, Kentucky with a population of 7,100. Average personal per capita income is decidedly below average, being $700 compared to $1,322 for Kentucky and $1,318 for Tennessee.

Agricultural employment equaled 30.5 percent in 1960 of the total employment of 36,100 and was the most important employment category. The area experienced a slight increase in total farm acres between 1954 and 1959 but an increase of $10 million in the total value of farm products sold. By 1959, the total value equaled $31.4 million. Crops and livestock products each accounted for about 40 percent of this figure. Slightly less than 300 acres were irrigated in 1959.

Although manufacturing was of only secondary importance in 1960, establishments employing 100 workers or over increased from 10 plants in 1958 to 15 in 1964. The most important industries were apparel,

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1/ Appendix I, Electric Power Resources and Requirements in the Ohio River Basin, Table 10.

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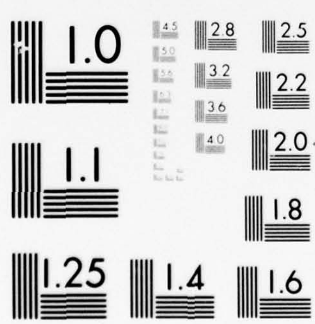


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

furniture and wood products, food processing, and chemicals and allied products. One hydropower generating plant is located at Lake Cumberland with a capacity of 270 megawatts. One thermal generating plant is at Burnside, Kentucky with a capacity of 100 megawatts.

Coal and crude oil extraction were the most important mining activities. In 1960, 1.4 million tons of coal and 281,000 barrels of oil were produced. These figures represent 2.1 percent and 1.3 percent respectively of Kentucky's total production for that year.

Minor Area S-5

Average personal per capita income in minor area S-5 at $793 was only 60 percent of the average $1,322 manifested by Kentucky. In 1960, 185,400 people resided in the area, 25 percent of which were urbanized. Middlesboro was the largest city with a population of 12,600.

Mining was the most important employment category in 1960 and largely dependent upon coal production. In that year, 8.8 million tons were extracted equaling 13.2 percent of Kentucky's total production.

Agricultural employment fell from 13,200 in 1950 to 5,100 in 1960. The total value of farm products sold between 1954 and 1959 increased from $8.3 million to $11.4 million. Of the latter figure, field crops accounted for 51.2 percent. Less than 100 acres were irrigated.

Manufacturing in the area is in a developing stage. Between 1958 and 1964, establishments employing 100 workers or over increased from five to nine plants. The most important industries in 1960 were furniture and wood products, food processing, apparel, and other nondurables. There is one thermal power generating plant in the area located in Bell County, Kentucky, with a capacity of 67.4 megawatts.

Projected Population and Industrial Activity

Population of the Cumberland subarea is projected to increase from 1.2 million in 1960 to nearly 2.7 million by 2020. In 1960, the subarea accounted for 6.4 percent of the total Ohio River Basin population but is expected to account for 7.7 percent by 2020. Table 6 shows the 1960 and projected population for the minor areas.

Agricultural output is expected to increase from $567 million in 1960 to $828 million by 2020. Manufacturing is projected to increase its output from $1.7 billion in 1960 to $10.4 billion by 2020.

Table 7 shows 1960 output, employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Cumberland subarea in the Projective Economic Study, twenty-one other counties have land area within the basin. These counties are listed in Table 8.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

Present and Projected Water Use

There are 96 water supply systems in the Cumberland River Basin serving a population of about 768,000. The average water use is 66.135 mgd or 98 gallons per capita per day.

Of the municipal use, 93 percent is from surface sources, and 7 percent is from ground sources, including springs. Nashville is the major area of municipal and industrial water use, accounting for 61 percent of the total municipal use and 85 percent of the total industrial use. Many smaller communities have ground water sources. Over 70 percent of the total municipal water withdrawal is taken from the Cumberland River.

The present municipal and industrial water use in the basin is listed by county and totaled for economic subareas and the basin in Table 9. The ascending number order of the minor areas corresponds to a general direction of travel from the mouth of the river toward its head.

In minor area S-1, the lower part of the basin, the two communities of Clarksville, Tennessee, and Hopkinsville, Kentucky, contain 86 percent of the population served by municipal systems and use 87 percent of the water delivered by municipal systems. There are eight smaller systems in this minor area.

In minor area S-2, which contains the counties farthest downstream in Tennessee, the major use is in the systems serving the Nashville metropolitan area. The four systems in Davidson County serve 94 percent of the total population served in this minor area and use 95 percent of the water delivered by the systems.

The S-3 minor area contains most of the remaining Tennessee counties in the basin. There are five cities with water systems serving a population of 10,000 or greater: Murfreesboro, Lebanon, Cookeville, Gallatin, and McMinnville. Six other communities have populations served between 2,500 and 10,000. The five largest communities include 66 percent of the population served and 71 percent of the water used.

In the S-4 minor area, Somerset, Kentucky, serving a population of 14,250 and Monticello, Kentucky, serving a population of 4,400, account for 62 percent of the population served and 47 percent of the water use in the minor area.

In the headwaters area, in minor area S-5, Middlesboro and Corbin, Kentucky, have 37 percent of the population served and 31 percent of the water use. The communities between 2,500 and 10,000 population served are Pineville, Cumberland, Lynch, Harlan, Barbourville, London, and Willismburg, Kentucky. These seven systems include 51 percent of the population served and 55 percent of the average daily water use.

In areas in the basin not included in the A. D. Little Projective Economic Study, the communities of Princeton, Kentucky, and Jellico, Tennessee, contain 79 percent of the population served and supply 81 percent of the average daily water use.

Based on projected increases in population and industrial activity, estimated water use in the Cumberland River Basin will increase from now to 2020 as indicated in Table 10. It is estimated that total municipal supplies and water supplied by industry for its own use will together increase by more than four times the present amount used.

The assumption is made in projecting water use for each of the minor areas that future areas of concentrated withdrawals will be the same as those existing now. In minor area S-1, daily water use is projected to increase to more than five times the present use by 2020, with the major increases probably occurring in the Hopkinsville, Kentucky, and Clarksville, Tennessee, areas. In 2020, water use estimated in the S-2 minor area, centering in Nashville and Davidson County, will be approximately 440 mgd, about five times the present average use. There will probably be some increase in use in the Springfield and Franklin, Tennessee areas also.

Projected water use in the S-3 minor area in middle Tennessee will rise to about six times its present level by 2020. The major increases could occur in the Cookeville, Murfreesboro, and Gallatin areas, and to a lesser extent, in the McMinnville and Lebanon areas. By 2020, in the S-4 minor area, where water use is very small, it is estimated that water use will increase fourfold, with a major share of this amount used at Somerset and Monticello, Kentucky.

In minor area S-5, water use is projected to be about 2.5 times the present use by 2020, with major withdrawals probably in the Middlesboro, Corbin, Harlan, London, and Barbourville areas. Princeton and Jellico show major increases in the projections for areas within the basin but outside the Projective Economic Study area. In these areas, use in 2020 is estimated at slightly more than three times current use.

Water Supply Problems

The projected total water supply figures shown in Table 10, the 1 day in 30 years low flow data given in Table 5, and availability of ground water as reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11 are problem areas with the approximate time of onset.

There are 25 communities in the Cumberland River Basin having populations between 1,000 and 2,500. Eleven of these will probably have a need to expand their municipal supplies over the projection period.

The two major water using communities of Clarksville, Tennessee, and Hopkinsville, Kentucky, in minor area S-1 are presently withdrawing or could draw municipal and industrial water from the Cumberland River if necessary, so no problems are expected. In the S-2 minor area, two problems are expected to develop in communities with populations over 2,500. Franklin, Tennessee, is in need of developing additional surface storage before 1980, and Springfield, Tennessee, will need to enlarge its present surface supply system or turn to additional surface development by 2000.

Smithville, Tennessee, one of the seven communities in minor area S-3, where problems may develop, should be able to satisfy its future need from Center Hill Reservoir. The other six communities that follow should be able to supply expected needs by additional development of present surface supplies or by building small impounding reservoirs. An impoundment along the East Fork of Stones River would assist in meeting needs at Woodbury by 2000 and at Murfreesboro by 1980. McMinnville, Tennessee, should consider expansion of its surface supply by 1980, and Smyrna could probably meet its future needs by turning to Stones River to supplement present ground sources.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11

CUMBERLAND RIVER BASIN

Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Springfield, Tenn.	S-2			X	
Franklin, Tenn.	S-2	X			
Woodbury, Tenn.	S-3			X	
Livingston, Tenn.	S-3			X	
Cookeville, Tenn.	S-3			X	
Murfreesboro, Tenn.	S-3		X		
Smithville, Tenn.	S-3		X		
Smyrna, Tenn.	S-3		X		
McMinnville, Tenn.	S-3		X		
Monticello, Ky.	S-4				X
Pineville, Ky.	S-5				X
Cumberland, Ky.	S-5				X
Barbourville, Ky.	S-5				X
London, Ky.	S-5				X
Jellico, Tenn.	*			X	

*Not in Projective Economic Study Area.

An expansion of present sources could probably meet the expected need at Cookeville by 2000, and Livingston could consider developing a small impoundment by 2000 to meet increased needs.

Problems in the S-4 and S-5 minor areas all have later dates of onset. At Monticello, further development of existing ground sources should be considered by 2020. Pineville could also consider either ground or surface sources to meet its 2020 needs. An addition to existing surface sources would be required at London by 2020, while new impoundments could be needed at Cumberland and Barbourville also by 2020. In the areas outside of the Projective Economic Study, Jellico, by 2000, will need to consider development of new surface sources, should existing ground sources prove to be incapable of further development.

VI WATER QUALITY CONTROL

Present and Projected Waste Loads

Present waste loads generated are shown in Table 12. The domestic and commercial organic pollutional load generated is currently estimated at 364,000, of which 53 percent is in minor area S-2 (Middle Tennessee around Nashville), 18 percent in minor area S-3 (Cumberland Plateau area), and 14 percent in minor area S-5 (headwaters area). The same three minor areas contribute 73, 11 and 3 percent, respectively, of the estimated industrial pollutional loading. The downstream reaches of minor area S-1 contribute 11 percent of the estimated industrial loading.

Major sources of municipal organic wastes generated are in Nashville, Clarksville, Murfreesboro, Springfield, Gallatin, Lebanon, and Cookeville, Tennessee, and Middlesboro and Hopkinsville, Kentucky. These nine communities account for 75 percent of the municipal wastes generated. Major sources of industrial organic waste loads generated are at Nashville, Clarksville, Old Hickory, and Lebanon, Tennessee. These four communities account for 87 percent of the estimated industrial organic waste loads generated.

Shown in Table 13 are the present and projected raw waste loads generated for the minor areas. Waste loads are projected to increase by 2020 to more than 4.5 times the present amount in minor areas S-1 and S-2, to more than five times the present amount in minor area S-3, to more than three times the present amount in minor area S-4, and to more than double the present amount in minor area S-5.

Water Quality Control Problems

Listed in Table 14 are areas and approximate beginning date where water quality problems are anticipated to occur during periods of low streamflow due to residual wastes after secondary treatment.

Although the major sources of wastes in the basin are on the main stem of the Cumberland River, most of the problem areas are found in smaller communities and are of a localized nature. There is adequate dilution water in the main channel to accomodate the expected waste load from Nashville in 2020, providing that secondary waste treatment methods are in use.

TABLE 14

CUMBERLAND RIVER BASIN

Present and Projected Water Quality Control Problem Areas

Stream	Vicinity 1/	Economic Area	Approximate Beginning Date Present	1980	2000	2020
North Fork Little River	Hopkinsville 2/	S-1	X			
Sulphur Fork Creek	Springfield	S-2	X			
West Fork Harpeth River	Franklin	S-2	X			
East Fork Stones River	Woodbury	S-3	X			
West Fork Stones River	Murfreesboro	S-3	X			
Town Creek	Gallatin	S-3	X			
Sinking Creek	Lebanon	S-3	X			
Short Creek	Cookeville	S-3	X			
Town Branch	Livingston	S-3	X			
Rockcastle Creek	Jamestown	S-4	X			
Elk Spring Creek	Monticello 2/	S-4	X			
Sinking Creek	Somerset 2/	S-4	X			
Lynn Camp Creek	Corbin 2/	S-5	X			
Whitley Branch	London 2/	S-5	X			
Yellow Creek	Middlesboro 2/	S-5	X			
Martins Fork	Harlan 2/	S-5				X
Poor Fork	Cumberland 2/	S-5			X	
Looney Creek	Lynch 2/	S-5	X			
Eddy Creek	Princeton 2/	O-1	X			

1/ Located in State of Tennessee unless otherwise noted.
2/ Kentucky.

The design flow of North Fork Little River at Hopkinsville, Kentucky, is less than 3 cfs. Total summer flows presently needed are in the order of 20 cfs and will increase to 30 cfs in 1980, 50 cfs in 2000, and 90 cfs by 2020. Since this community is in the headwaters region of the stream, storage of the magnitude required does not appear to be available and intensive treatment is indicated.

The West Fork of Stones River at Murfreesboro, Tennessee, has a design flow of less than 1 cfs. Present flow requirements are slightly higher than those below Hopkinsville, but future requirements will be similar to those below Hopkinsville.

Flow requirements in Short Creek below Cookeville, Town Creek below Gallatin, Sulphur Fork Creek below Springfield, and Sinking Creek below Lebanon in Tennessee, are all projected to be of the same magnitude. Present flows needed are in the order of 10 to 15 cfs, and flows in the order of 20 cfs will be needed by 1980 on stream reaches below all four towns. In 2000, requirements will be 30 to 40 cfs, and in 2020, 50 to 60 cfs. Design flows at all four locations are less than 4 cfs, and all towns presently have secondary treatment.

Below Middlesboro, Kentucky in Yellow Creek and Jamestown, Tennessee, in Rockcastle Creek, present flow needs are 10 cfs. These needs will increase to 12 cfs in 1980, 20 cfs in 2000, and 25 to 30 cfs by 2020. The design flow in Yellow Creek below Middlesboro is 3 cfs and is greater than at Jamestown, but additional flow will be required in both locations.

Flow needs below Livingston on Town Branch, Princeton on Eddy Creek, and Woodbury on East Fork Stones River, at present are about 5 cfs, increasing to 10 cfs by 1980, 12 cfs by 2000, and 15 cfs by 2020. Design flows of the streams below these towns are less than 1 cfs. If storage of water for quality control release is not feasible holding ponds could possibly be used as a means of reducing pollution in critical flow periods if sufficient land area can be made available.

The design flow of the West Fork Harpeth River is also less than 1 cfs. There is need at present for 12 cfs and with the high growth rate projected for minor area S-2, there will be a need below Franklin of 15 cfs in 1980, 20 cfs in 2000, and 36 cfs in 2020. In areas such as this and near Princeton, Springfield, Lebanon, Gallatin, and Jamestown, the topography is not well suited to reservoir construction, and other means including waste diversion to larger bodies of water or intensive treatment may have to be found for maintaining water quality.

In the upper reach of the basin, a flow requirement of 10 cfs by 2020 is projected in Looney Creek below Lynch, where the design flow is less than 1 cfs. Meeting this flow need will also provide adequate dilution for residual organic loads at the downstream communities of Cumberland on Poor Fork and Harlan, providing the point of discharge from Harlan is relocated from Martin's Fork to the Cumberland River.

Localized problems requiring up to a total of 10 cfs by 2020 are expected to occur on small streams below Monticello, Corbin, Somerset and London. All of these towns except London are near large reservoirs, so the long term quality problem may require advanced treatment methods where recreation is a factor. There are undoubtedly other small tributaries adversely affected by discharge of residual wastes remaining after adequate treatment, but it is beyond this report to define the scope of all of them.

Other quality problems are those caused by acid mine drainage and thermal power generating plants. Streams which are reported to be affected by mine drainage in Kentucky are: Poor Fork and Cranks Creeks in Harlan County; Left Fork Straight Creek, Right Fork Straight Creek and Stoney Fork in Bell County; Patterson Creek, Jellico Creek and Pleasant Run in Whitley County; Marsh Creek, Rock Creek and Wolf Creek in McCreary County; Raccoon Creek, Little Raccoon Creek and Wood Creek in Jackson County. Streams which are reported to be affected by mine drainage in Tennessee are: Clear Fork and Straight Creek in Claiborne County; White Oak Creek and Hickory Creek in Campbell County; Phillips Creek, Flat River, Sulphur Creek and Brimstone Creek in Scott County; Hall Creek in Morgan County; Obey River in Clay County; E. Fork Obey River, Officer Creek, Meadow Creek and Little Laurel Creek in Fentress County; and Cub Creek in Overton County. In addition to these streams there are numerous other intermittent tributaries in most of the counties mentioned which contribute acid runoff following periods of rain.

Heat is added to streams of the basin by four thermal power plants having installed capacities of 29.5, 1050, 67.4, and 100 megawatts respectively. The first two plants contribute to a rise in the temperature of Old Hickory Reservoir, the third adds heat to a short stretch of the Cumberland River in its upper reach and the fourth adds heat to Lake Cumberland.

TABLES

TABLE 1

CUMBERLAND RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky		Adair	7.7
Tennessee		Anderson	20.6
Kentucky	*	Bell	96.2
Tennessee		Bledsoe	32.7
Kentucky		Caldwell	44.7
Tennessee		Campbell	58.5
"	*	Cannon	98.1
Kentucky		Casey	10.2
Tennessee	*	Cheatham	100.0
Kentucky	*	Christian	63.6
Tennessee		Claiborne	17.2
Kentucky		Clay	7.2
Tennessee	*	Clay	81.1
Kentucky	*	Clinton	100.0
Tennessee		Coffee	10.4
Kentucky		Crittenden	21.8
"	*	Cumberland	89.1
Tennessee		Cumberland	26.4
"	*	Davidson	100.0
"	*	DeKalb	100.0
"	*	Dickson	75.9

TABLE 1 (cont'd)

CUMBERLAND RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Tennessee	*	Fenstress	96.5
"		Grundy	57.4
Kentucky	*	Harlan	86.6
Tennessee		Hickman	1.6
"	*	Houston	47.2
Kentucky	*	Jackson	55.4
Tennessee	*	Jackson	100.0
Kentucky	*	Knox	90.6
"	*	Laurel	100.0
"		Letcher	15.5
"		Lincoln	22.9
"		Livingston	37.8
"		Logan	39.4
"	*	Lyon	83.8
"	*	McCreary	100.0
Tennessee	*	Macon	27.5
Kentucky		Metcalfe	1.6
"	*	Monroe	31.5
Tennessee	*	Montgomery	100.0
"		Morgan	21.0
"	*	Overton	100.0

TABLE 1 (cont'd)

CUMBERLAND RIVER BASIN

Counties in Basin

State		County	Percent o. Land Area in Basin
Tennessee	*	Pickett	100.0
Kentucky	*	Pulaski	100.0
Tennessee	*	Putnam	100.0
"	*	Robertson	100.0
Kentucky	*	Rockcastle	82.6
"	*	Russell	70.6
Tennessee	*	Rutherford	100.0
"	*	Scott	100.0
"		Sequatchie	20.2
Kentucky		Simpson	22.7
Tennessee	*	Smith	100.0
"	*	Stewart	71.3
"	*	Sumner	70.6
Kentucky	*	Todd	64.3
"	*	Trigg	83.1
Tennessee	*	Trousdale	100.0
"	*	Van Buren	100.0
"	*	Warren	100.0
Kentucky	*	Wayne	100.0
Tennessee	*	White	100.0

TABLE 1 (cont'd)

CUMBERLAND RIVER BASIN

Counties in Basin

State		County	Percent of Land Area in Basin
Kentucky	*	Whitley	100.0
Tennessee	*	Williamson	83.7
"	*	Wilson	100.0

*Counties considered in Projective Economic Study of Ohio River Basin.

TABLE 2

CUMBERLAND RIVER BASIN

Major Tributaries and Drainage Areas

Tributary	Drainage Area (Sq. Miles)	Length of Stream (miles)	Miles from confluence with Ohio River
Cumberland River	17,914	694	0
Little River	601	70	59
Red River	1,456	56	125
Harpeth River	866	117	153
Stones River	937	39	206
Caney Fork River	2,585	144	309
Obey River	947	58	381
Big South Fork River	1,382	77	516
Rockcastle River	763	53	546
Laurel River	289	38	552

TABLE 3

CUMBERLAND RIVER BASIN

Population of Principal Communities

City	County	State	1910	1920	1930	1940	1950	1960
Nashville	Davidson	Tenn.	110,364	118,342	153,866	167,402	174,307	170,874
Inglewood 1/ 2/	"	"	-	-	-	-	-	26,527
Woodmont-Green Hill Glendale 1/ 2/	"	"	-	-	-	-	-	23,161
Clarksville	Montgomery	Tenn.	8,548	8,110	9,242	11,831	16,246	22,021
Hopkinsville	Christian	Kentucky	9,419	9,696	10,746	11,724	12,526	19,465
Murfreesboro	Rutherford	Tenn.	4,679	5,367	7,993	9,495	13,052	18,991
Donelson 1/	Davidson	"	-	-	-	-	1,765	17,195
Woodbine-Radner Glencliff 1/ 2/	"	"	-	-	-	-	-	14,485
Madison 1/ 2/	"	"	-	-	-	-	-	13,583
Middlesboro	Bell	Kentucky	7,305	8,041	10,350	11,777	14,482	12,607
Lebanon	Wilson	Tenn.	3,659	4,084	4,656	5,950	7,913	10,512
Springfield	Robertson	"	2,085	3,860	5,577	6,668	6,506	9,221
McMinnville	Warren	"	2,299	2,814	3,914	4,649	7,577	9,013
Gallatin	Sumner	"	2,399	2,757	3,050	4,829	5,107	7,901
Cookeville	Putnam	"	1,848	2,395	3,738	4,364	6,924	7,805
Corbin	Knox Whitley	Kentucky	2,689	3,406	8,036	7,893	7,744	7,119
Somerset	Pulaski	"	4,491	4,672	5,506	6,154	7,097	7,112
Franklin	Williamson	Tenn.	2,924	3,123	3,377	4,120	5,475	6,977
Princeton	Caldwell	Kentucky	3,015	3,689	4,764	5,389	5,388	5,618

1/ Unincorporated
2/ Part of Nashville, Tennessee urbanized area.

TABLE 4

CUMBERLAND RIVER BASIN

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Pool Area (Acres)	Storage (thousand acre-feet) Flood Control	Water Supply	Power	Other
Lake Cumberland	F, P	35,820	2,094		2,142	1,853
Dale Hollow	F, P	21,880	353		496	857
Center Hill	F, P	14,590	762		492	838
J. Percy Priest 1/	F, P, R	10,570	350		34	268
Old Hickory	P, N	19,550	125 2/		63	357
Cheatham	N, P	5,630			20	84
Lake Barkley	F,N,P,R	45,210	1,472		259	610
Cordell Hull 1/	P, N, R	9,820	86 2/		54	205
Laurel 1/	P, R	4,200			185	25[illegible]
Great Falls Lake	P	2,270			49	
Lake Morris	F, W	175	1	3		
Lake Boxley	F, W	165	2	2		
Cranks Creek	R	200				10
Pine Mountain Lake	R	110				

F - Flood Control
P - Power
N - Navigation
W - Water Supply
R - Recreation

1/ Under Construction
2/ Surcharge - Not allocated to flood storage

[redacted]

[redacted]

TABLE 5

CUMBERLAND RIVER BASIN

Flow Data [2/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs) Nat.	7 Day Avg. 1 in 10 Yr. Low Flow (cfs) Reg. [1/]	1 Day in 30 Yrs. Low Flow (cfs) Nat.	1 Day in 30 Yrs. Low Flow (cfs) Reg. [1/]
Cumberland River								
Barbourville, Kentucky	960	1,722	0.2	47,900	8.3			
Williamsburg, Kentucky	1,607				8.6			
Cumberland Falls, Kentucky	1,977	3,146	4	59,600	16			
Rowena, Kentucky	5,790	8,867	0	162,000	96	325	55	38.5
Celina, Tennessee	7,307	11,220	69	145,000	190	840	120	218
Carthage, Tennessee	10,700	17,020	366	210,000	520	3,125	340	1,880
Old Hickory, Tennessee	11,674					3,450		2,280
Nashville, Tennessee	12,841				565	3,500	345	2,375
Cheatham, Tennessee	14,160				610	3,650	375	2,500
Clarksville, Tennessee	15,897				645	3,800	390	2,650
Dover, Tennessee	16,417	24,310	414	280,000	710	3,850	450	2,675
Smithland, Kentucky	17,913	27,920	453	201,000	810	4,100	545	2,950
New River								
New River, Tennessee	382	708	0	44,300				
South Fork Cumberland								
Stearns, Kentucky	954	1,767	11	69,600				
Obey River								
Dale Hollow Dam, Tennessee	935	1,395		41,400				
Collins River								
McMinnville, Tennessee	624	1,126	35	75,300				
Caney Fork								
Rock Island, Tennessee	1,640	3,193	25	210,000				
Stones River								
Murfreesboro, Tennessee	128				.3			
Donelson, Tennessee	834	1,376	10	68,700				
Harpeth River								
Kingston Springs, Tenn.	687	934	12	60,000				
Red River								
Adams, Tennessee	678	972	30	42,000				

1/ Low flow regulated by Wolf Creek, Dale Hollow, Center Hill, Old Hickory and Cheatham Reservoirs.

2/ Excerpted from Hydrology of the Ohio River Basin, Appendix C,

TABLE 6

CUMBERLAND RIVER BASIN

Economic Subarea S
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation S-1									
Kentucky	Christian	56,900	19,500						
Tennessee	Houston	4,800	0						
Kentucky	Lyon	5,900	0						
Tennessee	Montgomery	55,600	26,500						
"	Stewart	7,900	0						
Kentucky	Todd	11,400	0						
"	Trigg	8,900	0						
	Subtotal	151,400	46,000	159,600		214,800		290,000	
Area Designation S-2									
Tennessee	Cheatham	9,400	0						
"	Davidson	399,700	350,600						
"	Dickson	18,800	5,000						
"	Robertson	27,300	9,200						
"	Williamson	25,300	7,000						
	Subtotal	480,500	371,800	750,400		988,500		1,344,000	
Area Designation S-3									
Tennessee	Cannon	8,500	0						
"	Clay	7,300	0						
"	DeKalb	10,800	0						
"	Jackson	9,200	0						
"	Macon	12,200	0						

TABLE 6 (cont'd)

CUMBERLAND RIVER BASIN

Economic Subarea S
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation S-3 (cont'd)									
Tennessee	Overton	14,700	2,800						
"	Putnam	29,200	7,800						
"	Rutherford	52,400	22,600						
"	Smith	12,100	0						
"	Sumner	36,200	7,900						
"	Trousdale	4,900	0						
"	Van Buren	3,700	0						
"	Warren	23,100	9,000						
"	White	15,600	4,500						
"	Wilson	27,700	10,500						
	Subtotal	267,600	65,100	380,200		522,200		670,000	
Area Designation S-4									
Kentucky	Clinton	8,900	0						
"	Cumberland	7,800	0						
Tennessee	Fentress	13,300	0						
Kentucky	McCreary	12,500	0						
"	Monroe	11,800	0						
Tennessee	Pickett	4,400	0						
Kentucky	Pulaski	34,400	10,800						
"	Russell	11,100	0						
Tennessee	Scott	15,400	0						
Kentucky	Wayne	14,700	2,900						
	Subtotal	134,300	13,700	120,000		148,700		188,000	

TABLE 6 (cont'd)

CUMBERLAND RIVER BASIN

Economic Subarea S
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation S-5									
Kentucky	Bell	35,300	15,800						
"	Harlan	51,100	12,300						
"	Jackson	10,700	0						
"	Knox	25,300	4,600						
"	Laurel	24,900	4,000						
"	Rockcastle	12,300	0						
"	Whitley	25,800	9,200						
	Subtotal	185,400	45,900	123,400		151,700		188,000	
Total Subarea S		1,219,200	542,500	1,533,600	777,000	2,025,900	1,180,000	2,680,000	1,920,000

TABLE 7

CUMBERLAND RIVER BASIN

Economic Subarea S
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation S-1													
Kentucky	Christian	13,500	1,760										
Tennessee	Houston	1,400	360										
Kentucky	Lyon	1,600	210										
Tennessee	Montgomery	14,900	2,690										
"	Stewart	2,400	420										
Kentucky	Todd	4,000	560										
"	Trigg	2,800	370										
	Subtotal	40,600	6,370	141.7	124	149	217	190	214	487	269	320	878
Area Designation S-2													
Tennessee	Cheatham	3,100	760										
"	Davidson	153,400	35,470										
"	Dickson	6,400	1,990										
"	Robertson	9,800	2,310										
"	Williamson	8,800	1,780										
	Subtotal	181,500	42,310	946.7	141	131	206	195	162	383	271	208	739

TABLE 7 (cont'd)

CUMBERLAND RIVER BASIN

Economic Subarea S
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation S-3													
Tennessee	Cannon	3,300	1,140										
"	Clay	2,400	500										
"	DeKalb	4,000	1,360										
"	Jackson	3,000	510										
"	Macon	4,500	1,050										
"	Overton	4,700	1,500										
"	Putnam	9,800	2,680										
"	Rutherford	15,300	2,600										
"	Smith	4,300	820										
"	Sumner	13,300	3,830										
"	Trousdale	1,900	380										
"	VanBuren	1,000	260										
"	Warren	8,300	2,540										
"	White	5,200	1,860										
"	Wilson	10,400	2,600										
	Subtotal	91,400	23,630	411.8	142	184	265	205	290	564	299	406	1080
Area Designation S-4													
Kentucky	Clinton	2,500	340										
"	Cumberland	2,700	310										
Tennessee	Fentress	3,300	1,320										
Kentucky	McCreary	2,000	260										
"	Monroe	3,900	500										
Tennessee	Pickett	1,500	560										
Kentucky	Pulaski	10,300	1,670										
"	Russell	3,000	270										
Tennessee	Scott	3,500	970										
Kentucky	Wayne	3,800	670										
	Subtotal	36,500	6,870	104.6	112	170	232	146	262	454	195	399	891

TABLE 7 (cont'd)

CUMBERLAND RIVER BASIN

Economic Subarea S
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation S-5													
Kentucky	Bell	7,300	1,090										
"	Harlan	11,000	600										
"	Jackson	2,200	140										
"	Knox	4,800	640										
"	Laurel	6,100	600										
"	Rockcastle	3,000	300										
"	Whitley	5,800	620										
	Subtotal	40,200	3,990	85.7	105	126	194	135	158	418	175	206	893
Total Area S		390,200	83,170	1690.5	133	150	222	187	210	438	259	289	876

*In millions of 1960 dollars.
**1960 = 100

TABLE 8

CUMBERLAND RIVER BASIN

Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Adair	P-3	Green
Tennessee	Anderson	*	
"	Bledsoe	*	
Kentucky	Caldwell	O-1	Ohio-Evansville
Tennessee	Campbell	*	
Kentucky	Casey	P-3	Green
Tennessee	Claiborne	*	
Kentucky	Clay	M-4	Licking-Kentucky-Salt
Tennessee	Coffee	*	
Kentucky	Crittenden	O-1	Ohio-Evansville
Tennessee	Cumberland	*	
"	Grundy	*	
"	Hickman	*	
Kentucky	Letcher	M-4	Licking-Kentucky-Salt
"	Lincoln	M-2	Licking-Kentucky-Salt
"	Livingston	O-1	Ohio-Evansville
"	Logan	P-1	Green
"	Metcalfe	P-3	Green
Tennessee	Morgan	*	
"	Sequatchie	*	
Kentucky	Simpson	P-3	Green

* - Not included in Projective Economic Study of Ohio River Basin.

TABLE 9

CUMBERLAND RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation S-1											
Kentucky	Christian	2	26,750	750	26,000	1.552	.052	1.500	58	Lakes, Wells	0.4
Tennessee	Houston	1	1,280	1,280		.100	.100		78	Spring	0
Kentucky	Lyon	1	400		400	.028		.028	70	Cumberland River	0
Tennessee	Montgomery	1	35,000		35,000	2.500		2.500	71	Cumberland River	0.9
"	Stewart	1	1,000	1,000		.070	.070		70	Well	0
Kentucky	Todd	3	4,420	4,420		.256	.256		58	Well, Springs	0
"	Trigg	1	1,980	1,980		.095	.095		48	Spring	0
	Subtotal	10	70,830	9,430	61,400	4.601	0.573	4.028	65		1.3
Area Designation S-2											
Tennessee	Cheatham	1	1,740	1,740		.090	.090		52	Spring	0.1
"	Davidson	4	353,000		353,000	40.625		40.625	115	Cumberland River	39.0
"	Dickson	1	500	500		.020	.020		40	Wells	0
"	Robertson	3	11,025	1,935	9,090	.964	.164	.800	87	Sulfur Fk.Crk., Wartrace Lake, Springs, Wells	0.3
"	Williamson	2	9,000	300	8,700*	1.021	.021	1.000	113	Harpeth River, Springs	0.2
	Subtotal	11	375,265	4,475	370,790	42.720	.295	42.425	114		39.6

TABLE 9 (cont'd)

CUMBERLAND RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation S-3											
Tennessee	Cannon	1	2,620	2,620		.150	.150		57	Springs	.2
"	Clay	1	1,330	1,330		.075	.075		56	Wells	.1
"	DeKalb	3	3,850	3,850		.206	.206		54	Wells, Springs	0
"	Jackson	1	2,000	2.000		.100	.100		50	Wells	0
"	Macon	0									0
"	Overton	1	4,200	4,200		.280	.280		67	Wells	0
"	Putnam	4	16,330	4,330	12,000	1.565	.265	1.300	96	Falling Water R., Springs, Wells	0.5
"	Rutherford	3	29,410	4,410	25,000	2.299	.399	1.900	78	East Fk.Stone R., Springs, Wells	0.7
"	Smith	1	3,000		3,000	.250		0.250	83	Cumberland River	0
"	Sumner	3	18,425		18,425	1.453		1.453	79	Old Hickory Lake, Cumberland River	1.5
"	Trousdale	1	1,600		1,600	.150		.150	94	Cumberland River	0
"	Van Buren	0									0
"	Warren	1	12,000		12,000	1.000		1.000	83	Barren Fork River	0
"	White	1	6,400	6,400		.430	.430		67	Spring	0
"	Wilson	3	15,510	1,310	14,200	2.028	.093	1.935	131	Old Hickory Lake, Cumberland R., Wells	0.7
	Subtotal	24	116,675	30,450	86,225	9.986	1.998	7.988	86		3.7
Area Designation S-4											
Kentucky	Clinton	1	1,820	1,820		.150	.150		82	Springs	0
"	Cumberland	1	1,750		1,750	.100		.100	57	Cumberland River	0
Tennessee	Fentress	1	1,400		1,400	.300		.300	214	Lake	0
Kentucky	McCreary	1	1,100		1,100	.079		.079	72	Lakes	0
"	Monroe	0									0
Tennessee	Pickett	0									0
Kentucky	Pulaski	2	14,985		14,985	1.050		1.050	70	S.Fk.Cumberland R., Lake Cumberland	0.2
"	Russell	2	2,300	2,300		.135	.135		59	Springs	0.1
Tennessee	Scott	1	2,150	2,150		.200	.200		93	Wells	0.2
Kentucky	Wayne	1	4,400	4,400		.180	.180		41	Wells	0.1
	Subtotal	10	29,905	10,670	19,235	2.194	.665	1.529	74		0.6

TABLE 9 (cont'd)

CUMBERLAND RIVER BASIN

Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation S-5											
Kentucky	Bell	7	18,170	4,150	14,020	1.038	.237	.801	57	Cumberland R.,Fern L.,Springs,Wells	0.3
"	**Harlan**	21	22,655	8,320*	14,335	2.209	1.240	.969	98	Clover Fk.,Cumberland R., Poor Fk.Crk., Gap Branch Mine, Wells,Looney Crk.	0.1
"	Jackson	0									0
"	Knox	1	5,080		5,080	.750		.750	148	Cumberland River	0
"	Laurel	1	6,200		6,200	.300		.300	48	Sinking Creek	0.1
"	Rockcastle	2	1,030		1,030	.087		.087	85	Rockcastle River, Roundstone Creek	0
"	Whitley	2	13,800		13,800	1.285		1.285	93	Laurel River, Cumberland River	0.1
	Subtotal	34	66,935	12,470	54,465	5.669	1.477	4.192	85		0.6
Other Areas in Basin											
Kentucky	Caldwell	1	8,500	8,500		.600	.600		71	Spring	.1
Tennessee	Campbell	1	3,000	3,000		.180	.180		60	Well	0
"	Claiborne	1	600	600		.042	.042		70	Spring	0
"	Cumberland	1	500		500	.020		.020	40	Lake	0
Kentucky	Livingston	2	1,000	1,000		.063	.063		63	Wells	0
"	Logan	1	925		925	.060		.060	65	South Fork River	0
	Subtotal	7	14,525	13,100	1,425	.965	.885	.080	67		.1
	TOTAL	96	674,135	80,595	593,540	66.135	5.893	61.242	98		45.9

* Combined Supplies

TABLE 10

CUMBERLAND RIVER BASIN

Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Area Designation S-1												
From Central Supplies	70,830	65	4.6	84,300	85	7.2	133,000	95	12.6	219,000	105	23.0
Industrial			1.3			2.4			4.6			7.8
Subtotal			5.9			9.6			17.2			30.8
Area Designation S-2												
From Central Supplies	375,265	114	42.7	660,500	127	84.0	1,013,000	140	142.0	1,689,000	150	253.0
Industrial			39.6			67.0			108.0			187.0
Subtotal			83.3			151.0			250.0			440.0
Area Designation S-3												
From Central Supplies	116,675	86	10.0	187,800	96	18.0	301,000	105	31.6	469,000	117	55.0
Industrial			3.7			8.3			15.8			27.5
Subtotal			13.7			26.3			47.4			82.5
Area Designation S-4												
From Central Supplies	29,905	74	2.2	30,500	90	2.8	44,000	98	4.3	67,000	110	7.4
Industrial			0.6			1.2			2.1			3.9
Subtotal			2.8			4.0			6.4			11.3
Area Designation S-5												
From Central Supplies	66,935	85	5.7	50,900	95	4.8	72,300	105	7.6	109,000	116	12.6
Industrial			0.6			0.9			1.7			3.0
Subtotal			6.3			5.7			9.3			15.6
Other Areas in Basin												
From Central Supplies	14,525	67	1.0	15,700	85	1.3	20,000	95	1.9	28,000	105	2.9
Industrial			0.1			.2			.3			.5
Subtotal			1.1			1.5			2.2			3.4
Cumberland River Basin												
From Central Supplies Total	674,135	98	66.2	1,029,700	115	118.1	1,583,300	126	200.0	2,581,000	137	353.9
Industrial Total			45.9			80.0			132.5			229.7
GRAND TOTAL			112.1			198.1			332.5			583.6

TABLE 12

CUMBERLAND RIVER BASIN

Base Municipal and Industrial Organic Waste **Production**

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation S-1						
Kentucky	Christian	1	19,465	North Fork Little River	19,465	5,600
Tennessee	Houston	0	0		0	400
Kentucky	Lyon	0	0		0	0
Tennessee	Montgomery	1	13,200	Cumberland River	13,200	34,500
"	Stewart	0	0		0	300
Kentucky	Todd	0	0		0	200
"	Trigg	0	0		0	100
	Subtotal	2	32,665		32,665	41,100
Area Designation S-2						
Tennessee	Cheatham	1	1,250	Cumberland River	1,250	800
"	Davidson	3	174,550	Cumberland River	174,550	260,000
"	Dickson	0	0		0	0
"	Robertson	1	10,000	Sulphur Creek	10,000	3,900
"	Williamson	1	6,850	Harpeth River	6,850	3,500
	Subtotal	6	192,650		192,650	268,200

TABLE 12 (cont'd)

CUMBERLAND RIVER BASIN

Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Area Designation S-3						
Tennessee	Cannon	1	1,560	East Fork Stones River	1,560	4,000
"	Clay	0	0		0	1,700
"	DeKalb	1	2,175	Gray's Branch	2,175	1,200
"	Jackson	0	0		0	500
"	Macon	0	0		0	1,000
"	Overton	1	2,400	Town Brook to Roaring River	2,400	1,700
"	Putnam	1	9,800	Shorts Creek	9,800	5,600
"	Rutherford	2	18,600	W.Fk.Stones River, Stones River	18,600	5,700
"	Smith	1	1,500	Cumberland River	1,500	1,000
"	Sumner	1	10,000	Town Creek to Station Camp Creek	10,000	4,100
"	Trousdale	1	1,540	Little Goose Creek	1,540	6,600
"	VanBuren	0	0		0	0
"	Warren	1	8,000	Barren Fork River	8,000	300
"	White	1	2,150	Calf Killer River	2,150	900
"	Wilson	2	8,240	Sinking Creek, Round Lick Creek	8,240	4,900
	Subtotal	13	65,965		65,965	39,200
Area Designation S-4						
Kentucky	Clinton	1	1,885	Clear Fork Branch	1,885	500
"	Cumberland	1	1,690	Cumberland River	1,690	200
"	McCreary	0	0		0	0
"	Monroe	0	0		0	0
"	Pulaski	1	7,110	Sinking Creek to Pitman Creek	7,110	2,100
"	Russell	2	1,915	Big Lilly Creek, Town Branch	1,915	300
"	Wayne	1	2,940	Elk Spring Creek to Beaver Creek	2,940	500
Tennessee	Fentress	0	0		0	500
"	Pickett	0	0		0	1,000
"	Scott	1	875	Pine Creek	875	1,200
	Subtotal	7	16,415		16,415	6,300

TABLE 12 (cont'd)

CUMBERLAND RIVER BASIN

Base Municipal and Industrial Organic Waste **Production**

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*	
					Domestic & Commercial	Estimated Industrial
Area Designation S-5						
Kentucky	Bell	2	15,785	Yellow Creek, Cumberland River	15,785	4,500
"	Harlan	5	14,715	Poor Fk., Martin's Fk., Looney Crk.	14,715	2,400
"	Jackson	0	0		0	0
"	Knox	1	3,210	Cumberland River	3,210	200
"	Laurel	1	4,035	Whitley Brook	4,035	2,200
"	Rockcastle	1	1,175	Town Branch to Roundstone Creek	1,175	0
"	Whitley	2	10,600	Lynn Camp Creek, Cumberland River	10,600	900
	Subtotal	12	49,520		49,520	10,200
Other Areas in Basin						
Kentucky	Caldwell	1	5,620	Eddy Creek	5,620	1,000
Tennessee	Campbell	1	1,340	Elk Creek	1,340	0
	Subtotal	2	6,960		6,960	1,000
	TOTAL	42	364,175		364,175	366,000

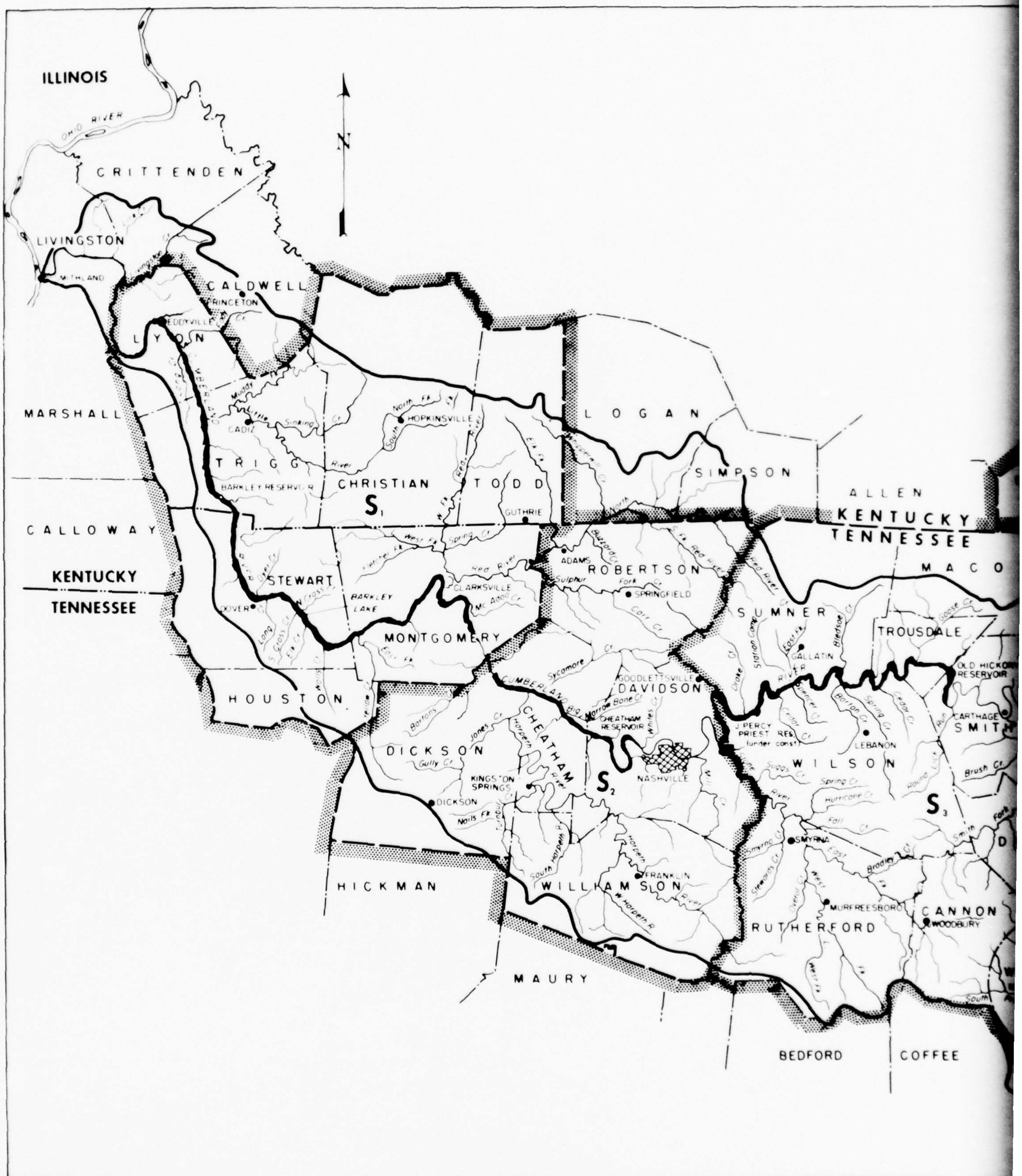
***NOT* to be interpreted as waste loads to the stream.**

TABLE 13

CUMBERLAND RIVER BASIN

Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Area Designation S-1				
Domestic and Commercial	32,665	38,900	61,100	101,000
Industrial	41,100	75,200	143,800	246,000
Subtotal	73,765	114,100	204,900	347,000
Area Designation S-2				
Domestic and Commercial	192,650	339,100	520,200	867,000
Industrial	268,200	451,000	727,000	1,261,000
Subtotal	460,850	790,100	1,247,200	2,128,000
Area Designation S-3				
Domestic and Commercial	65,965	106,200	170,200	265,000
Industrial	39,200	88,200	167,800	292,000
Subtotal	105,165	194,400	338,000	557,000
Area Designation S-4				
Domestic and Commercial	16,415	16,700	24,000	37,000
Industrial	6,300	12,600	22,400	40,000
Subtotal	22,715	29,300	46,400	77,000
Area Designation S-5				
Domestic and Commercial	49,520	37,600	53,500	81,000
Industrial	10,200	15,900	29,400	51,000
Subtotal	59,720	53,500	82,900	132,000
Other Areas in Basin				
Domestic and Commercial	6,960	7,100	10,200	16,000
Industrial	1,000	2,000	3,600	6,000
Subtotal	7,960	9,100	13,800	22,000
Cumberland River Basin				
Domestic and Commercial Total	364,175	545,600	839,200	1,367,000
Industrial Total	366,000	644,900	1,094,000	1,896,000
GRAND TOTAL	730,175	1,190,500	1,933,200	3,263,000


ILLINOIS
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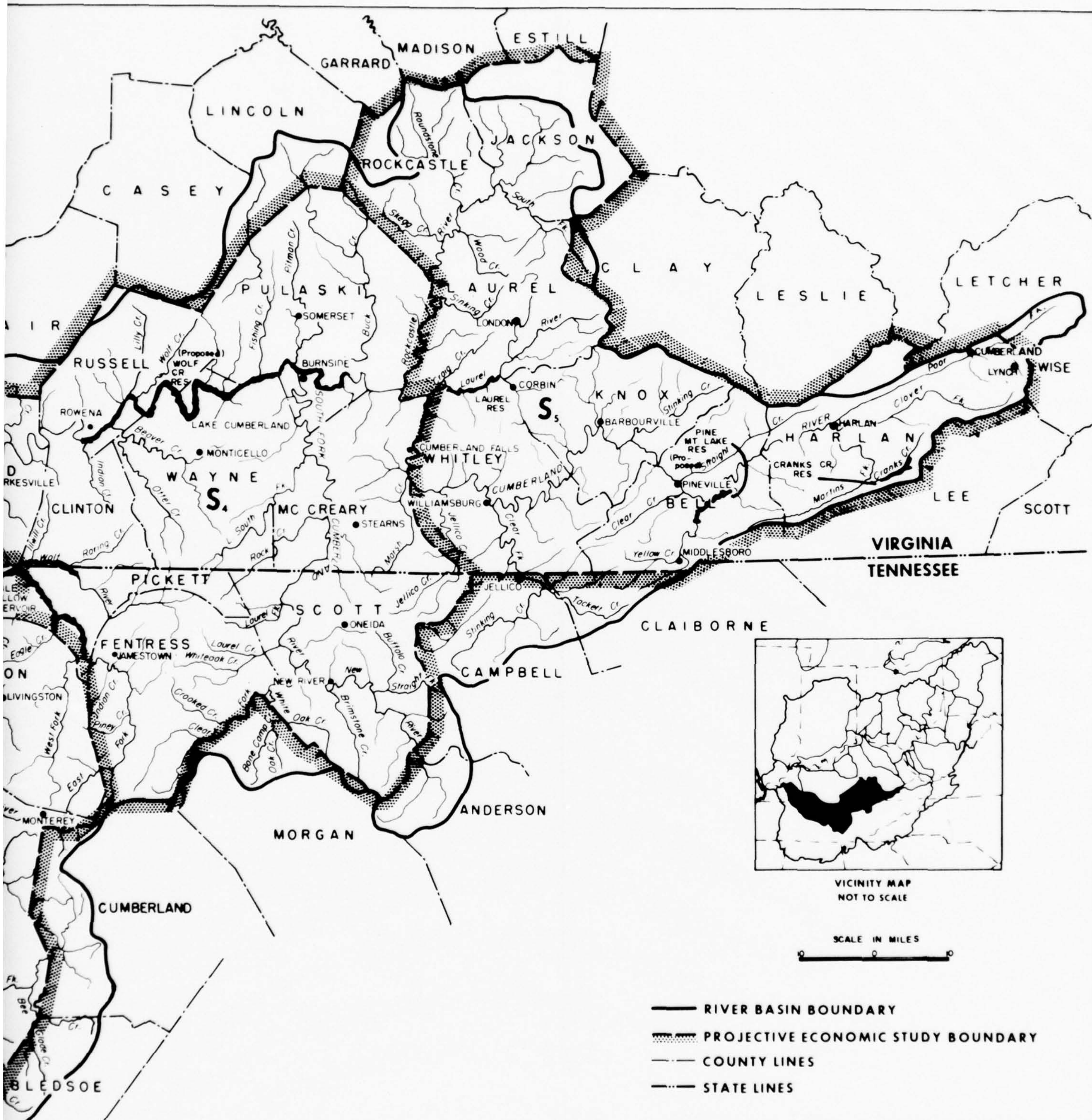
BARKLEY RESERVOIR
CHRISTIAN
HOPKINSVILLE
TODD
GUTHRIE
LOGAN
SIMPSON
ALLEN
KENTUCKY
TENNESSEE
CALLOWAY
KENTUCKY
TENNESSEE
S_1
STEWART
DOVER
BARKLEY LAKE
CLARKSVILLE
MONTGOMERY
ADAMS
ROBERTSON
SPRINGFIELD
SUMNER
GALLATIN
TROUSDALE
OLD HICKORY RESERVOIR
MACO
HOUSTON
DICKSON
CHEATHAM
CUMBERLAND RIVER
GOODLETTSVILLE
DAVIDSON
CHEATHAM RESERVOIR
NASHVILLE
KINGSTON SPRINGS
S_2
J. PERCY PRIEST RES. (under const.)
LEBANON
WILSON
CARTHAGE
SMITH
S_3
SMYRNA
HICKMAN
FRANKLIN
WILLIAMSON
MURFREESBORO
RUTHERFORD
CANNON
WOODBURY
MAURY
BEDFORD
COFFEE

KENTUCKY
TENNESSEE
GARRARD
MADISON
ESTILL
LINCOLN
JACKSON
ROCKCASTLE
CASEY
PULASKI
LAUREL
ADAIR
RUSSELL
METCALFE
SOMERSET
BURNSIDE
LONDON
CORBIN
LAUREL RES
KNOX
BARBOURVILLE
(Proposed) WOLF CR RES
ROWENA
LAKE CUMBERLAND
MONTICELLO
CUMBERLAND
BURKESVILLE
WAYNE
S_4
S_5
CUMBERLAND FALLS
WHITLEY
WILLIAMSBURG
MONROE
CLINTON
MC CREARY
STEARNS
ALLEN
PICKETT
MACON
DALE HOLLOW RESERVOIR
CELINA
SCOTT
ONEIDA
JELLICO
FENTRESS
JAMESTOWN
CAMPBELL
TROUSDALE
JACKSON
OVERTON
LIVINGSTON
GALLATIN
OLD HICKORY RESERVOIR
NEW RIVER
CORDELL HULL RES (under const)
CARTHAGE
SMITH
LEBANON
WILSON
COOKEVILLE
MONTEREY
PUTNAM
MORGAN
ANDERSON
S_3
CUMBERLAND
SMYRNA
DEKALB
SMITHVILLE
CENTER HILL RESERVOIR
WHITE
SPARTA
MURFREESBORO
CANNON
WOODBURY
GREAT FALLS LAKE
ROCK ISLAND
VAN BUREN
WARREN
McMINNVILLE
BLEDSOE
BEDFORD
COFFEE
GRUNDY
SEQUATCHIE



OHIO RIVER BASIN FRAMEWORK STUDY

CUMBERLAND RIVER BASIN
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

12 33

FIGURE 12 1

OHIO MAIN STEM

No. 13

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I SUMMARY

Municipal and Industrial Water Supply Problems

The Ohio River serves as a source for major withdrawals for municipal and industrial water supply along most of its length. In addition, unconsolidated glacial outwash and non-glacial river alluvium along the river valley are important source of supply for municipal and industrial water use. These unconsolidated deposits and fluvial sediments are referred to hereafter simply as alluvial deposits.

The larger communities dependent on the river for surface supply are East Liverpool, Steubenville, Ironton, Portsmouth and Cincinnati, Ohio; Wheeling, and Huntington, West Virginia; Ashland, Newport, Covington, Louisville, Henderson and Paducah, Kentucky and New Albany and Evansville, Indiana. The larger communities dependent on ground sources obtained from the alluvium are Bellevue, Coraopolis and Aliquippa, Pennsylvania; Martins Ferry, Ohio; Parkersburg and Weirton, West Virginia; the Louisville Water District and Owensboro, Kentucky and Jeffersonville, Indiana. Marietta is supplied with ground water from the alluvium of the Muskingum Valley.

Other larger water using communities in the main stem and minor tributary drainage areas are Ambridge, Pennsylvania, located on the Ohio River but using an upland source; Salem, Ohio, in the Little Beaver River tributary basin; Washington and Canonsburg, Pennsylvania using surface sources in the Chartiers Creek subbasin; and Lancaster and Athens, Ohio using ground supplies in the Hocking River subbasin.

Ample supplies of water exist in the main stem of the Ohio River to meet projected needs providing the quality of the water is protected. There are a number of communities in upland areas and tributary drainage basins where shortages of water supply will occur within the study period. However, further development of present sources of supply can meet these needs.

Water Quality Control Problems

Under present conditions of treatment, monitoring by the Ohio River Sanitation Commission indicated that, during the year 1964, dissolved oxygen concentrations at times in the main stem below Pittsburgh, Pennsylvania; Huntington, West Virginia; Cincinnati, Ohio and Louisville, Kentucky were less than 4.0 mg/l during periods of lower flows.

Based on the assumption that all collectable organic wastes will receive secondary treatment before discharge to the streams of the basin, the critical reaches from the dissolved oxygen standpoint in the main stem Ohio River are below Pittsburgh, Pennsylvania and Cincinnati, Ohio. If flow needs are met at these two points, intermediate and downstream needs will also be met.

In addition to problems associated with low dissolved oxygen concentrations, low pH (5.0) values were observed in the upper Ohio River and high pH (9.0) values were observed at Evansville in the lower reach. Problems with producing a potable drinking water have been observed at Huntington, West Virginia and Cincinnati, Ohio.

In tributary basins, unsatisfactory stream conditions exist due to residual organic waste discharges in Robinson Run below McDonald, Pennsylvania; Chartiers Creek below Washington and Canonsburg, Pennsylvania; the Middle Fork of the Little Beaver River below Salem, Ohio; the Hocking River below Lancaster, Logan and Athens, Ohio; Little Raccoon Creek below Wellston, Ohio; the Mill Creek at Cincinnati, Ohio; Laughery Creek below Batesville, Indiana; Big Indian Creek below Corydon, Indiana; Blue River below Salem, Indiana and Saline River below Harrisburg, Illinois.

II DESCRIPTION OF STUDY AREA

Location and Boundaries

Areas along both banks of the Ohio River main stem draining directly to the river in addition to drainage areas of other tributaries not previously discussed are included in this portion of the study. Among these tributaries are the Hocking River in Ohio; Twelvepole Creek in West Virginia; Tygarts Creek in Kentucky; Mill Creek in Ohio; Blue River in Indiana; Tradewater River in Kentucky and Saline River in Illinois.

The Allegheny and Monongahela Rivers join at Pittsburgh, Pennsylvania, to form the Ohio River. From Pittsburgh, the Ohio River flows generally southwest for 981 miles to Cairo, Illinois, where it joins the Mississippi River. Major cities along its banks are Pittsburgh, Pennsylvania; Wheeling, and Huntington, West Virginia; Cincinnati, Ohio; Covington and Louisville, Kentucky; and Evansville, Indiana.

The total fall of the main stem is 429 feet between Pittsburgh and Cairo. Parts of 6 states lie within the area draining directly to the main stem. After the river flows 40 miles through Pennsylvania, it serves as the boundary between Ohio, Indiana, and Illinois on the north, and West Virginia and Kentucky on the south. Tables 1a through 1e list the counties located in the Ohio River main stem drainage area and the percentage of their land area draining directly to the main stem. Table 2 gives information about a number of tributaries to the main stem which are not discussed elsewhere in this report. Figures 13-1 through 13-5 depict the location of the drainage described in this portion of the study.

Physical Features

In Pennsylvania, the Ohio River flows within the unglaciated part of the Appalachian Plateau. Chartiers Creek and Raccoon Creek, the major tributaries entering from the south in Pennsylvania, drain a hilly unglaciated section of the plateau. Between the Pennsylvania border and Wheeling, West Virginia the river continues to flow through an area unmodified by glacial action, so the topography remains rather rugged and dissected. It is drained by many short streams entrenched in fairly deep, narrow valleys.

The valley of the Ohio River at Point Pleasant, West Virginia, contains alluvial deposits about two and one-half miles wide and in some places these deposits are over 100 feet thick. In some places, the river flows along bedrock cliffs, but where alluvial deposits are present, they are commonly more than one-half mile wide. At Parkersburg, West Virginia, they are three-quarters of a mile wide and up to 55 feet thick.

Generally the main stem valley is characterized as has been described above. Immediately along the river there are alluvial deposits of varying widths. In the lower stretch of the river, these deposits range from one mile wide at Madison, Indiana, to 10 miles wide at Owensboro, Kentucky. The valley is bordered by an almost continuous band of rough unglaciated land from the mountainous headwater regions of western Pennsylvania through the hilly country of southeastern Ohio and the Knobs section of Kentucky and southern Indiana to the Ozark uplift of southern Illinois.

The minor tributary drainage areas are generally hilly and rough. The Hocking River drains an area of 1,200 square miles in southeastern Ohio and except for the glaciated headwaters area near Lancaster, Ohio, the basin is hilly with moderately steep slopes. The Tygarts Creek subbasin in northeastern Kentucky has moderately steep slopes and the Twelvepole Creek in West Virginia has steepsided, rugged drainage. The major exception to this pattern is Mill Creek Basin, which contains much of the Cincinnati metropolitan area. The Mill Creek valley is nearly two miles wide and it follows the course of the ancestral Ohio River northward toward Hamilton, Ohio.

There are three major reservoirs on the minor tributaries of the Ohio. Two of these are in Ohio and are presently operated as a part of the U. S. Army Corps of Engineers plan for flood protection in the Ohio Basin. The third reservoir is under construction on Twelvepole Creek.

Climate

Average annual precipitation along the main stem decreases in the general direction of travel upstream. Near the mouth, the annual average rainfall is 45 to 50 inches with this amount being recorded south of the river and slightly lesser amounts to the north of the river. Along most of the main stem, the annual average precipitation is 40 to 45 inches, while immediately to the north it may be less. Along the river in the State of Pennsylvania the rainfall average is from 35 to 40 inches annually.

Average January temperatures are 37°F in Paducah, Kentucky, in the southern third of the basin, 32°F in Cincinnati, Ohio and 31°F in Pittsburgh, Pennsylvania. Average July temperatures are 80°F in Paducah, 76°F in Cincinnati and 74°F in Pittsburgh. The growing season, as designated by the average number of frost-free days, is 208 days in Paducah, 192 days in Cincinnati and 185 days in Pittsburgh.

Principal Communities and Industries

Listed in Tables 3a-3e are the larger communities of the main stem drainage area with their populations from 1910 to 1960. The Pennsylvania section contains the heavily industrialized Pittsburgh area with major manufacturing categories being primary metals, fabricated metals, including structural steel, electrical and nonelectrical machinery, food processing and other durable goods. Primary metals, fabricated metals, chemicals and other durables are major employement categories in the upper Ohio and Huntington reaches of the river.

In the Cincinnati reach of the river, major categories of manufacturing employment are machine tools, machinery, transportation equipment, food processing, chemicals and printing. The Louisville area is also diversified in its manufacturing. Principal types of industry are food, machinery, lumber and furniture, fabricated metals and chemicals. The Evansville area is not as heavily industrialized. Major employment categories are agriculture, mining, electrical machinery, food processing, lumber and furniture. Availability of water has played a large part in the selection of location for numerous plants along the main stem, since primary metal, chemical and food processing industries are all large water using industries.

III WATER RESOURCES

Surface Water Resources

Quantity

Listed in Table 4 is information about the reservoirs on minor tributaries of the Ohio River. Construction is just beginning on East Lynn Reservoir on Twelvepole Creek. The other reservoirs are operated primarily for flood protection. A major purpose of West Fork Reservoir on Mill Creek is to even out the pumping load at the flood protection barrier dam at the mouth of Mill Creek in Cincinnati. Flows on the main stem are influenced by numerous reservoirs on tributary streams and by navigation dams on the Ohio River itself. As of 1964, 38 reservoirs had been completed by the Corps of Engineers, and nine more were under construction. The various states also have reservoirs, largely for recreation. Shown in Tables 5a and 5b is information excerpted from data prepared by the Corps of Engineers[1] about flows on the main stem and minor tributaries.

Quality

The waters of the main stem of the Ohio River are classified as moderately hard to hard depending on the season of the year. Concentrations show an inverse relationship to flows. When the flow is high in the winter and early spring, hardness values range from around 80 to 100 mg/l with the higher values occurring in the downstream reaches. At the lower flow and high concentration periods of the year, maximum hardness may range from 200 to 275 mg/l, with the higher values occurring in the middle and upper stream reaches.

Immediately downstream from Pittsburgh, the Ohio is sometimes acid. The pH of the Monongahela at Pittsburgh during a recent year ranged from 4.1 to 7, while that of the Allegheny ranged from 3.7 to 7.2 with most values between 6.2 and 7.2. The pH was under 7 quite often. Progressing downstream, the pH values gradually rose until at Evansville the range of pH values was from 6.8 to 9.0.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

At times, there are very low chloride concentrations, in the order of 5 to 15 mg/l. Maximum chlorides range from 70 to 140 mg/l, with the higher values being recorded at Huntington and Cincinnati although higher values approaching 200 mg/l were observed at Parkersburg, West Virginia in 1964, reflecting the influence of a heavy salt load carried by the Muskingum River. High sulfate concentrations occur at low flows, again with the maximum observed values, between 250 and 300 mg/l, coming at the upstream stations. Concentrations observed during the high runoff season will vary from 20 to 100 mg/l.

Changes in quality are also affected by discharge of organic wastes from municipal sewerage systems and industrial outfalls. During periods of low flow in the main stem, low dissolved oxygen concentrations (less than 4.0 mg/l) have been recorded below Pittsburgh, Pennsylvania; Huntington, West Virginia; Cincinnati, Ohio and Louisville, Kentucky. Present treatment is less than secondary at all of these locations.

Water treatment problems associated with tastes and odor are encountered at times at Huntington, West Virginia; Cincinnati, Ohio and Evansville, Indiana.

Some of the factors which affect quality of water in the Ohio River are mine drainage; discharge of ground water from limestone formations; extraction of brines for industrial processing and discharge of unwanted residues; oil field brine discharges and discharges from various industrial processes such as steel mill blast furnaces, inorganic and organic chemical manufacturing and coking operations and residual organic wastes discharged by municipalities.

Ground Water Resources

Quantity

Glacial and alluvial valley fill along the course of the Ohio River is the principal source of ground water in this region. There is a plentiful supply and continuous recharge from surface flows assures that this situation will continue. The ground water conditions along the main stem are reported in detail by the U. S. Geological Survey[1/] and the following condensation is excerpted from their study.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

The valley of the Ohio River from Pittsburgh to Marietta contains glacial sediments of varying hydraulic characteristics which were transported by melt water streams in the Allegheny and Beaver River Basins. The valley is generally 0.6 to 1 mile wide though it occasionally narrows to 0.4 mile, but at Moundsville, West Virginia, it is about 2 miles wide. Thicknesses of saturated sediment range from 20 to 60 feet. Wells from the valley fill usually yield more than 100 gpm, often 300 gpm, and infrequently as much as 1,500 gpm.

Outwash sand and gravel deposits, especially in the upper part of the Hocking valley, provide large quantities of water in this minor tributary drainage area. The thickest and most permeable outwash deposits occur near Lancaster. They range from 120 to 200 feet in thickness and yield as much as 500 gpm to individual wells. South of Lancaster, the deposits become thinner and less permeable. Throughout the valley, fine sand and poorly sorted gravel layers limit the sustained yield of wells by clogging well screens, thus making it frequently necessary to redevelop the wells or drill new ones.

Along the main stem from Maysville, Kentucky, to Madison, Indiana, the alluvial valley is as narrow as one-half mile and is more than two miles wide at some locations. The thickness of the valley fill is 100 to 150 feet. Maximum yields from wells in the fill, range from 250 to 1,000 gpm, though just west of Covington some reported yields are from 25 to 200 gpm. In this region, wells located close to the river yield water of better quality than wells drilled near the valley wall in which water is more highly mineralized.

The Mill Creek, Ohio valley follows the course of the ancestral Ohio River. The trough of this ancient valley was subsequently filled with glacial outwash and lake clay. In general, the sand and gravel aquifer in the Mill Creek valley is overlain by about 100 feet of relatively impermeable lake deposits. These clay and silt deposits impede recharge from the stream to the underlying permeable outwash deposits.

Much of Cincinnati's industry is located in the Mill Creek valley. Therefore, the valley fill aquifer has long been pumped heavily for industrial water supplies. Recharge to this aquifer in the industrialized area has been estimated to be about 8.5 mgd. Total pumpage, however, has for many years ranged from 10 to 13 mgd, resulting in a perennial overdraft of this aquifer and declining ground water levels.

In the reach from Madison to Cairo, the alluvial deposits range in width from one mile near Madison to more than 10 miles near Owensboro, and in thickness from 90 to 150 feet. Finer grained sediments generally cover the coarser glacial sediments, so that the rate of recharge is less than in areas, as near Louisville, where river erosion has exposed the coarse grained sand and gravel. Maximum yields from wells in this reach range up to 1,500 gpm.

Quality

Water withdrawn from the alluvium along the Ohio is usually classed as hard. In the upper reaches, hardness concentrations range from 130 to 400 mg/l. In the reach from Maysville to Madison, hardness is from 250 to 350 mg/l, and downstream from Madison the range is from 150 to 600 mg/l.

Sulfate concentrations from wells in the upstream valley are higher than the other locations, ranging from 50 to 200 mg/l, while in the regions downstream, the maximum normally found is 70 mg/l and the minimum may be as low as 5 mg/l. Chlorides are almost always less than 60 mg/l, but are typically less than 20 or 30 mg/l in the middle or lower valley. Iron concentrations are lowest in the middle valley, usually less than 0.2 mg/l. Treatment would be required for domestic use in the other sections, as values range up to 3.5 mg/l.

In Hocking River subbasin, hardnesses range from 250 to 410 mg/l, chlorides from 2 to 35 mg/l, and total dissolved solids from 300 to 560 mg/l. Iron concentrations are such as to suggest treatment depending on the use, ranging from 0.1 to 2.4 mg/l.

Mill Creek valley waters are very hard with concentrations of bicarbonate of 300 to 500 mg/l, moderate sulfate concentrations of 30 to 120 mg/l, low chlorides of 5 to 30 mg/l, and a range of iron values of 0.5 to 4 mg/l.

IV THE ECONOMY

The Ohio River main stem direct drainage and minor tributaries economic area consists generally of a single tier of counties of the various states lying generally north and south of the Ohio River. Where larger minor tributaries such as the Hocking River in Ohio, the Saline River in Illinois, and the Tradewater River in Kentucky drain into the Ohio River, an effort was made to include the major portion of these drainage areas in the respective economic areas of the Projective Economic Study.

For the purpose of evaluating water supply and water quality control needs, Economic Area C, Pittsburgh S.M.S.A., is included with the main stem drainage, as it is located at the confluence of the Allegheny and Monongahela Rivers. Organic wastes from the Pittsburgh area influence largely the needs for quality control in the Upper Ohio portion of the Ohio River. The remainder of the main stem drainage area is divided into five additional reaches: Upper Ohio, Subarea E; Huntington, Subarea H; Cincinnati, Subarea K; Louisville, Subarea N and Evansville, Subarea O. The portion of the Ohio River in Subarea C extends from Pittsburgh, Pennsylvania, to the west boundary of the State of Pennsylvania; the Upper Ohio Subarea extends from the west boundary of Pennsylvania to below Parkersburg, West Virginia; the Huntington Subarea extends from Parkersburg, West Virginia, to below Portsmouth, Ohio; the Cincinnati Subarea extends from Portsmouth, Ohio to Carrollton, Kentucky; the Louisville Subarea extends from Carrollton to Cloverport, Kentucky; and the Evansville Subarea extends from Cloverport, Kentucky, to the confluence of the Ohio River with the Mississippi River at Cairo, Illinois.

Following are descriptions of each of the economic subareas comprising the main stem drainage system.

Pittsburgh Standard Metropolitan Statistical Area-Subarea C

The Pittsburgh Subarea of the Projective Economic Study lies entirely in Pennsylvania. The entire subarea also composes the Pittsburgh Standard Metropolitan Statistical Area and contains the lower reach of the Monongahela River watershed, the lower reach of the Allegheny River watershed, the lower reach of the Beaver River watershed and of the Ohio River direct drainage area from Pittsburgh to the Pennsylvania border. The counties in the subarea are listed in Tables 6a-1 and 7a-1 and shown on Figure 13-1, page 13-108. The entire subarea lies within the area designated as the Appalachian Region.

Economic Profile

The population of the Pittsburgh Subarea was 2,405,400 in 1960, 81.8 percent of which was urbanized. The area had an average of 788 persons per square mile. Average personal per capita income was $1,945 compared to $1,855 for Pennsylvania. There are 11 larger cities in the area, Pittsburgh being the largest with a population of 604,300. McKeesport in the Monongahela River drainage area, is next with a population of 45,500. Nine other cities in the subarea are within the 12,000-24,000 population range.

Manufacturing is the most important employment category. However, total manufacturing employment is expected to manifest a small absolute decline through the year 2000. Between 1958 and 1964, in the four county area, manufacturing establishments employing 100 workers or over declined from 368 to 321, with Allegheny County accounting for 45 of the total 47 plants. Allegheny County, the most important county in the area, accounted for 184 of the total 321 plants. The most important industries in the subarea are primary metal, machinery (including electrical machinery), fabricated metal, and other durables. There are 22 thermal power generating plants located in the subarea having a total generating capacity of 2,961.2 megawatts.

Mining activity is the second most important employment category and is dominated by coal extraction. In 1960, 18.8 million tons of coal were produced equaling 28.3 percent of Pennsylvania's total production. The remaining activity in mining is confined to a small amount of oil production, 311,000 barrels in 1960, and to stone, sand and gravel extraction.

The value of agricultural products sold increased $3.1 million between 1954 and 1959 to a total of $32.5 million by 1959. Approximately 64 percent of the latter figure was accounted for by livestock products. One hundred and fifty thousand acres were taken out of farm production between 1954 and 1959. In 1959, 650 acres were irrigated.

Projected Population and Industrial Activity

The Pittsburgh Subarea population is projected to increase from 2,405,400 in 1960 to 2,654,000 by 1980 and to 3,300,000 by 2020. Table 6a-1 shows the base and projected population for Subarea C. In 1960, the population of the Pittsburgh Subarea accounted for 12.6 percent of the total Ohio River Basin population but is expected to account for only 9.5 percent by the year 2020.

Agricultural output is projected to decline slightly from \$83 million in 1960 to \$78.4 million by 1980 and then increase to \$106 million by the year 2010. Total output in mining, however, is projected to manifest a steady increase from \$137.6 million in 1960 to \$480 million by 2010.

Although employment in manufacturing is expected to show a decline from the 1960 figure, manufacturing output is expected to increase from \$7.7 billion in 1960 to \$21.1 billion by 2010.

Table 7a-1 shows 1960 output, employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the subarea are shown as indices using 1960 as the base.

Upper Ohio-Subarea E

The Upper Ohio Subarea contains the area lying on both sides of the Ohio River beginning at the Pennsylvania border and extending downstream to the confluence of the Hocking River with the Ohio River. The subarea is roughly coextensive with the direct drainage watershed of the Ohio River along this stretch but also includes the lower reaches of the Muskingum and Hocking Rivers in Ohio and the lower reaches of the Little Kanawha River in West Virginia. The area is divided into two minor areas, E-1 and E-2, to facilitate future estimates of water requirements and waste loads. The E-1 area includes the eight southern counties, the E-2 area the seven northern counties. The counties in each minor area are listed in Tables 6a-2 and 7a-2 and shown on Figure 13-1, page 13-108. The entire subarea lies within the area designated as the Appalachian Region with the exception of Columbiana County, Ohio.

Economic Profiles

Minor Area E-1

The E-1 minor area population was 235,700 in 1960. Three larger cities are located in the area. They are Athens and Marietta, Ohio, and Parkersburg, West Virginia, with populations of 16,500, 16,800, and 78,300 respectively. Average personal per capita income in the counties comprising minor area E-1 was \$1,485 compared to an average of \$1,957 in Ohio and \$1,378 in West Virginia.

Manufacturing is the most important employment category in this minor area. Establishments employing 100 workers or over manifested a decline from a total of 43 in 1958 to 40 in 1964. The most important industries are chemicals and allied products, primary metals, other durables, and fabricated metals. A total of seven thermal power generating plants are located in the minor area having a total generating capacity of 1,557.8 megawatts.

Agricultural employment in 1960 (4,300) was only 35 percent of the 1950 figure, and 269,000 acres were taken out of farm production between 1954 and 1959. However, the total value of farm products sold was nearly the same in both 1954 and 1959, about $14.3 million. Seventy-seven percent of the latter figure was accounted for by livestock products. About 400 acres were irrigated in 1959.

Mining activity is confined primarily to coal, gas, and oil extraction. Coal production occurs primarily in Athens and Washington Counties in Ohio and amounted to about 550,000 tons. Gas and oil production figures are not published on a county basis in Ohio or in West Virginia, but the number of producing wells that are drilled each year is published by county in both states. In 1962, 48 new producing gas wells and 119 new producing oil wells were brought into production in the Ohio counties in the area, representing 19.8 percent and 20 percent respectively of the total number of new wells that year in Ohio. In 1963, 77 new gas wells and 60 new oil wells were brought into production in the West Virginia counties in the area representing 12 percent and 61.9 percent respectively of the total number of new wells that year in West Virginia.

Minor Area E-2

There are two Standard Metropolitan Statistical Areas in minor area E-2. Steubenville-Weirton, Ohio and West Virginia and Wheeling, West Virginia. The Steubenville-Weirton S.M.S.A. includes Jefferson County, Ohio and Brooke and Hancock Counties in West Virginia. Wheeling, West Virginia S.M.S.A. includes Marshall and Ohio Counties in West Virginia and Belmont County in Ohio. Columbiana County, Ohio is the only county in minor area E-2 not included in a Standard Metropolitan Statistical Area. Average personal per capita income amounted to $1,716. The 1960 population of E-2 was 465,000. Eight larger cities are located in the area, with Wheeling, West Virginia being the largest with a population of 53,400, Steubenville, Ohio next with a population of 32,500, and the others having populations between 12,000 and 24,000.

The total number of establishments employing 100 workers or more declined from 98 in 1958 to 95 in 1964. The most important industries are primary metals, other durables, machinery (including electrical machinery), and fabricated metals. Ten thermal power generating plants are located in minor area E-2 with a total generating capacity of 2,931.8 megawatts.

Bituminous coal extraction is of signal importance in the mining industry in the area. In 1960, 11.4 million tons were produced. All other activity is primarily confined to stone, sand, and gravel extraction.

Agriculture employment in 1960 (4,600) was 54 percent of the 1950 figure, ranking it below manufacturing, construction, and mining in the commodity group. Although 111,000 acres were taken out of farm production during the period 1954-1959, the total value of farm products sold increased approximately $1.5 million during the period to a 1959 total of $9.6 million. Dairy products, the dominate component, accounted for 41 percent of total farm sales in 1959. Approximately 100 acres were under irrigation in 1959.

Projected Population and Industrial Activity

The Upper Ohio Subarea population is project to increase from 700,700 in 1960 to 990,000 by 2020. Whereas the area population represented 3.7 percent of the Ohio River Basin population in 1960, it is projected to represent about 2.8 percent by 2020. Table 6a-2 shows the base and projected population for E-1 and E-2 minor areas.

While agricultural output is expected to increase from $96.1 million in 1960 to $126.9 million by 2020, mining output is expected to increase from $134.1 million in 1960 to $834.1 million by 2010. Output from manufacturing is expected to increase from $2.1 billion in 1960 to $5.5 billion by 2010.

Table 7a-2 shows 1960 output, employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Upper Ohio Subarea in the Projective Economic Study, fourteen other counties have land areas within the basin. These counties are listed in Table 8a.

Ohio-Huntington--Subarea H

The Ohio-Huntington Subarea of the Projective Economic Study is approximately centered on Huntington, West Virginia, and lies in Ohio, West Virginia, and Kentucky. It roughly encompasses

the drainage area of the Ohio River along this stretch but also contains the lower reach of the Scioto River in Ohio and the lower reaches of the Kanawha, Guyandotte, Big Sandy and Little Sandy Rivers in West Virginia. To facilitate estimates of future water requirements and waste loads, the subarea has been divided into three minor areas, H-1, H-2, and H-3. The four western counties of the subarea compose the H-1 area, the four southern counties compose the H-2 area, and H-3 contains the six eastern counties. The counties in each minor area are listed in Tables 6b and 7b and shown on Figure 13-2, page 13-109. All of the subarea lies within the area designated as the Appalachian Region.

Economic Profiles

Minor Area H-1

The minor area H-1 population was 145,900 in 1960 and the area contained one larger city, Portsmouth, Ohio, population 33,600. Average personal per capita income in the area at $1,295 was below the average of $1,957 for Ohio and $1,322 for Kentucky.

Manufacturing is the dominant employment commodity group in the area. Establishments employing 100 or more workers increased from a total of 10 in 1958 to 15 in 1964. Eleven of the 15 plants in 1964 were located in Pike County, Ohio. The most important industries are primary metals (Pike County has one plant employing over 1,000 workers), other nondurables, chemicals and allied products, furniture and wood products. One thermal power generating plant is located in the minor area, having a 21.5 megawatt capacity.

Agriculture has followed historical trends as noted elsewhere in the region. Employment in 1960 was less than half the 1950 figure, and 83,000 acres had been taken out of farm production between 1954 and 1959. The total value of farm products sold increased over the 1954 figure of $11.5 million to a total of $13.3 million in 1959. Less than 300 acres were irrigated by 1959.

Mining activity is confined largely to extraction of stone, sand, gravel, and clay products. There were four producing gas wells drilled in 1962 in Scioto County, Ohio.

Minor Area H-2

Minor area H-2 is designated the Huntington-Ashland Standard Metropolitan Statistical Area. Sixty-two percent of the 1960 population of 254,800 lived in urbanized areas. The three larger cities are

Huntington, West Virginia, Ashland, Kentucky, and Ironton, Ohio having populations of 83,600, 31,300 and 15,000 respectively. Average personal per capita income in 1960 equaled $1,558 compared to $1,957 in Ohio, $1,378 in West Virginia, and $1,322 in Kentucky.

Manufacturing is the most important employment category in the area. Establishments employing 100 workers or over increased from 36 in 1958 to 40 in 1964. Cabell County, West Virginia accounted for one-half of the plants. The most important industries are primary metals, other durables, chemicals and allied products, and other nondurables. The thermal power generating plant that is located in the minor area has a capacity of 15 megawatts.

The 1960 agricultural employment figure of 1,700 represents only 30 percent of the 1950 figure, and 153,000 acres were taken out of farm production between 1954 and 1959. Nevertheless the total values of farm products sold in 1954 and 1959 were similar at about $5.5 million. By 1959, 200 acres were irrigated.

In 1960, 524,400 tons of coal were produced in the area, 86 percent coming from Lawrence County, Ohio. During the year 1962, 12 producing gas wells were brought into production.

Minor Area H-3

Minor area H-3 is a relatively sparsely settled area, having an average density of 50 persons per square mile compared to 237 persons in Ohio and 77 in West Virginia. The 1960 population was 131,000, and there were no cities of 10,000 population or over. Average personal per capita income was $1,214 in 1960 in contrast to 1,957 in Ohio and $1,378 in West Virginia.

Manufacturing is the most important employment category, although the number of establishments employing 100 workers or over declined from 16 in 1958 to 14 in 1964. The most important industries are primary metals, chemical and allied products, other durables, and food processing. Two thermal power generating plants are located in the area having a total capacity of 2,146.3 megawatts.

The total value of farm products sold in 1959 was maintained at the 1954 figure of $16.5 million, 68 percent of which was livestock products. However, 183,000 acres were taken out of farm production between 1954 and 1959, and the 1960 employment figure of 4,400 was only 41.5 percent of the 1950 figure. Less than 500 acres were irrigated in 1959.

Coal, gas, and oil extraction dominate the mining industry in the area. In the Ohio counties during 1960, 2.1 million tons of coal were produced, equaling six percent of Ohio's total production. During 1962, 14 new producing oil wells and 10 new producing gas wells were brought into production.

Projected Population and Industrial Activity

Population of the Ohio-Huntington Subarea is projected to increase from 531,700 in 1960 to 599,600 in 1980 and to 795,000 by the year 2020. The 1960 subarea population represented 2.8 percent of the entire Ohio River Basin population; by 2020 the subarea is projected to contain only 2.3 percent of the entire population. Table 6b shows the base and projected population for H-1, H-2, and H-3 minor areas.

Agricultural output is projected to increase from $118.6 million in 1960 to $145.7 million in 2010 while mining output is projected to increase from $69.9 million in 1960 to $453.9 million by 2010. Manufacturing output is expected to increase from $1.2 billion in 1960 to $5.7 billion in 2010.

Table 7b shows 1960 output, employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Ohio-Huntington Subarea in the Projective Economic Study, eight other counties have land areas within the basin. These counties are listed in Table 8b.

Ohio-Cincinnati--Subarea K

The Ohio-Cincinnati Subarea straddles the Ohio River and is centered on Cincinnati, Ohio. It includes portions of the States of Indiana, Kentucky, and Ohio and contains the lower reaches of the Miami and Little Miami Rivers in Ohio and the Licking River in Kentucky. The subarea has been divided into three minor areas, K-1, K-2, and K-3, to facilitate estimates of future water requirements

and waste loads. Minor area K-1 includes the five western counties of the subarea, K-2 the middle five counties, and K-3 the eastern four counties of the subarea. Listed in Tables 6c and 7c and shown on Figure 13-3, page 13-11, are the counties included in these minor areas. Three Ohio counties, Clermont, Brown, and Adams, are within the area designated as the Appalachian Region.

Economic Profiles

Minor Area K-1

The population in this minor area amounted to 64,500 in 1960, with no cities located in the area with populations of 10,000 or over. Twenty-four percent of the population lived in urbanized places. Average personal per capita income was $1,473 in 1960 compared to $1,832 in Indiana and $1,322 in Kentucky.

Manufacturing is the most important employment category in the area. Those establishments employing 100 workers or over increased from 11 in 1958 to 16 in 1964. The most important industries are food processing, other nondurables, other durables, and furniture and wood products. One thermal power generating plant is located in the area with a capacity of 518 megawatts.

Agriculture is next in importance and has followed historical trends. Whereas the 1960 employment of 3,700 was only 55 percent of 1950 employment, and whereas 34,000 acres have been taken out of farm production during the period 1954-1959, the total value of farm products sold was $3 million greater than the 1954 figure amounting to $20.2 million in 1959. Approximately 53 percent of this total was accounted for by livestock products. Approximately 350 acres were irrigated in 1959.

Mining activity is confined to stone, sand, and gravel extraction.

Minor Area K-2

Hamilton County in Ohio and Campbell and Kenton Counties in Kentucky compose the Cincinnati Standard Metropolitan Statistical Area. Ninety-one percent of the 1,174,000 population of the minor area resided in these three counties in 1960. The average personal per capita income in these three counties in 1960 was $2,103 compared to $1,670 in the remaining two counties. The average personal per capita incomes in Kentucky and Ohio for that year were $1,322 and

$1,957 respectively. The K-2 area averaged 815 persons per square mile. Three larger cities, Covington, Newport, and Fort Thomas, are located on the Kentucky side of the Ohio River with populations of 60,400, 30,100 and 14,900 respectively. Five larger cities are located on the Ohio side, Cincinnati and Norwood being the largest with populations of 502,600 and 34,600, respectively. The remaining three cities are in the 10,000-13,000 population range.

Manufacturing employment accounted for one-third of total employment in this minor area in 1960, the most important industries being machinery (including electrical machinery), food processing, chemicals and allied products, and printing and allied products. The number of establishments employing 100 workers or more increased from 260 in 1958 to 271 by 1964. Hamilton County accounted for 252 of the 1964 total and for 8 of the 11 new establishments. Nine thermal power generating plants and one pulp mill are located in the area having total capacities of 1,592.2 megawatts and 95 tons per day respectively.

Agricultural employment during the period 1950-1960, declined at an average annual rate of 5.9 percent. One hundred thousand acres were taken out of farm production between 1954 and 1959, but the value of farm products sold in 1959 was maintained at about the 1954 figure of $19.5 million. Crops and livestock products each accounted for about half of this figure. Approximately 770 acres were irrigated in 1959.

Mining activity is confined to stone, sand, and gravel extraction.

Minor Area K-3

The K-3 minor area had a 1960 population of 71,100 with no cities with populations of 10,000 or over. Average personal per capita income at $1,153 was below that for Ohio or Kentucky, of $1,957 and $1,322 respectively.

Agriculture is the most important employment category in this minor area. During the period 1950-1960, agricultural employment declined at an average annual rate of 4.7 percent to a 1960 total of 6,600. From 1960 to the year 2000, the annual rate of decline is expected to be only 2 percent. Nevertheless, the total value of farm products sold increased $2.7 million over the 1954 total, amounting to $27.7 million by 1959. Crops and livestock products each accounted for about 49 percent of the 1959 figure. Approximately 200 acres were irrigated in 1959.

The most important manufacturing industries are machinery (including electrical machinery), other nondurables, food processing, and transportation equipment excluding motor vehicles. There were seven establishments in 1958 employing 100 workers or over and eight such plants in 1964.

No mining employment was reported in 1960.

Projected Population and Industrial Activity

Population of the Ohio-Cincinnati Subarea is projected to increase from the 1960 population of 1.3 million to 1.9 million by the year 2000 and 2.2 million by 2020. The subarea contained 6.9 percent of the total Ohio River Basin population in 1960 and is expected to contain 6.4 percent by 2020. Table 6c shows the base and projected populations for the K-1, K-2, and K-3 minor areas.

Agricultural output in the subarea is expected to increase from $166 million in 1960 to $252 million by 2020. Mining output is projected to increase at a faster rate, from $11.3 million in 1960 to $48.3 million by 2010. The biggest gains in the subarea are projected to take place in manufacturing. Manufacturing output is expected to increase from $3.7 billion in 1960 to $17.9 billion by 2010.

Table 7c shows 1960 output, employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Ohio-Cincinnati Subarea in the Projective Economic Study, six other counties have land areas within the basin and are listed in Table 8c.

Ohio-Louisville--Subarea N

The Ohio-Louisville Subarea of the Projective Economic Study is located on either side of the Ohio River and is centered roughly on Louisville, Kentucky. Included in the area are the lower reaches of the Kentucky and Salt Rivers in Kentucky. The subarea has been

divided into three minor areas, N-1, N-2, and N-3, to facilitate estimates of future water requirements and waste loads. The N-1 minor area includes the four downstream counties, the N-2 minor area includes the middle five counties, and N-3 the three upstream counties of the subarea. The counties in each minor area are listed in Tables 6d and 7d and shown on Figure 13-4, page 13-111.

Economic Profiles

Minor Area N-1

Total 1960 population amounted to 61,200, 4.4 percent of which were classified as urban, and there were no cities with populations of 10,000 or over located in the area. Average personal per capita income was $1,160 in 1960 compared to $1,322 in Kentucky and $1,832 in Indiana.

Agriculture is the most important employment category in the minor area. The 1960 agricultural employment figure of 4,500 was only 54 percent of the 1950 figure. The number of acres in farm production declined slightly, from 809,000 acres in 1954 to 795,000 acres in 1959. The total value of farm products sold increased from $16 million in 1954 to $23.3 million in 1959. Poultry and poultry products accounted for an unusually large part of the latter amount (21.2 percent). Livestock products accounted for 52.9 percent of the 1959 total. Less than 100 acres were irrigated in 1959.

Manufacturing employment increased at an average annual rate of 4.8 percent from 1950 to 1960. There were four manufacturing establishments employing 100 workers or over in both 1958 and 1964. The most important industries are furniture and wood products, chemicals and allied products, food processing, and machinery (including electrical machinery).

No mining employment was reported for 1960.

Minor Area N-2

The 1960 population was 754,200, 82.3 percent classified as urban. The number of people per square mile averaged 542. Average personal per capita income was $1,824 compared to $1,322 in Kentucky and $1,832 in Indiana. The three counties of Clark and Floyd in

Indiana and Jefferson in Kentucky compose the Louisville Standard Metropolitan Statistical Area. Five larger cities are located in the area, Louisville, Kentucky, and New Albany, Indiana, being the largest with respective populations of 390,600 and 37,800. The other three cities are in the 10,000-20,000 population range.

Manufacturing is the most important employment category. In 1964, there were 142 manufacturing establishments employing 100 workers or over. The most important industries are machinery (including electrical machinery), food processing, other nondurables, and fabricated metals. There are seven thermal power generating plants located in the minor area with a total capacity of 1,653.8 megawatts.

The total value of farm products sold increased from $18 million in 1954 to $20.3 million in 1959. Approximately 58 percent of the 1959 figure was accounted for by livestock products. Six hundred acres were under irrigation in 1959.

Mining activity is confined to stone, sand, gravel and clay.

Minor Area N-3

The 1960 population was 37,200, 35.7 percent classified as urban. Average personal per capita income equaled $1,344, compared to $1,322 in Kentucky and $1,832 in Indiana. Madison, Indiana, with a 1960 population of 10,500, is located in the minor area.

Agriculture is the most important employment category. The total value of farm products sold increased from $9.2 million in 1954 to $11.3 million in 1959. All crops accounted for 54 percent of the total 1959 figure. Less than 300 acres were irrigated by 1959.

Manufacturing establishments employing 100 or more workers increased from five in 1958 to 11 in 1964. The most important industries are other nondurables, machinery (including electrical machinery), food processing, and other durables. One thermal power generating plant is located in the minor area having a capacity of 1,304 megawatts.

Mining activity is confined mainly to stone, sand, and gravel production.

Projected Population and Industrial Activity

Population of the Ohio-Louisville Subarea is projected to increase from 852,600 in 1960 to 1,820,000 by the year 2020. The subarea population in 1960 accounted for 4.3 percent of the total Ohio River Basin population but is projected to contain 5.2 percent by the year 2020. Table 6d shows the base and projected population for N-1, N-2, and N-3 minor areas.

Agricultural output is projected to increase from $127.6 million in 1960 to $191.9 million by 2010. Mining output is projected to increase from $22.2 million in 1960 to $120.5 million by 2010.

The greatest gain is expected in Manufacturing. Total output is projected to increase from $2.2 billion in 1960 to $14.4 billion by the year 2010.

Table 7d shows 1960 manufacturing output, total employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Ohio-Louisville Subarea in the Projective Economic Study, five other counties have land areas within the basin. These counties are listed in Table 8d.

Ohio-Evansville--Subarea O

The Lower Ohio-Evansville Subarea of the Projective Economic Study straddles the lower reaches of the Ohio River and is centered roughly on Evansville, Indiana. It includes portions of the States of Illinois, Indiana, and Kentucky. The subarea is approximately coextensive with the direct drainage area of the Ohio River along this stretch. Included in the subarea is the lower reach of the Wabash River in Indiana and Illinois and portions of the lower reaches of the Tennessee, Cumberland and Green Rivers in Kentucky. To facilitate future estimates of water requirements and waste loads,

the subarea has been divided into three minor areas; 0-1, 0-2, and 0-3. Minor area 0-1 includes the 15 downstream counties, 0-2 the middle two counties, and 0-3 the six upstream counties. The counties in each minor area are listed in Tables 6e and 7e and shown in Figure 13-5, page 13-112.

Economic Profiles

Minor Area 0-1

The 1960 population of minor area 0-1 was 217,700, 33.9 percent classified as urban population. Average personal per capita income was $1,300 compared to $2,181 in Illinois and $1,322 in Kentucky. Two larger cities are located in the area , Harrisburg, Illinois and Paducah, Kentucky, with populations of about 9,200 and 34,500 respectively.

Manufacturing is the most important employment category. Establishments employing 100 workers or more increased from 16 in 1958 to 24 in 1964. The most important industries are chemicals and allied products, machinery (including electrical machinery), food processing, and furniture and wood products. Two thermal power generating plants are located in this minor area having a total capacity of 2,600.3 megawatts.

During the period 1954-1959, the total value of farm products sold increased from $46.2 million to $54.7 million. Approximately 53 percent of the latter figure was accounted for by livestock products. During this same period, 316,000 acres were taken out of farm production. Agricultural employment fell from 20,300 in 1950 to 9,700 in 1960. In 1959, 250 acres were irrigated.

Mineral extraction is an important industry in this minor area. In 1960, 7.1 million tons of coal were produced, 86 percent of which came from Union and Webster Counties in Kentucky and Saline County in Illinois. The total extraction of coal in the area equaled 15.5 percent of the total coal produced in Illinois and 10.7 percent of the total coal produced in Kentucky. Although total crude oil production data are not available at this time, the area produced in the neighborhood of five to six million barrels, almost all of it coming from Union and Webster Counties in Kentucky, Saline County in Illinois and Posey County in Indiana. In addition to coal and oil production, Hardin County in Illinois shipped 131,000 tons of

finished fluorspar in 1960, representing 59 percent of the total U. S. domestic shipments. Although data are not available, there is some fluorspar mining in Hardin and Pope Counties in Illinois and Crittenden, Caldwell and Livingston Counties in Kentucky.

Minor Area O-2

The two counties composing the O-2 minor area; Vanderburgh in Indiana and Henderson in Kentucky, are designated the Evansville Standard Metropolitan Statistical Area. The 1960 population was 199,300, 80.5 percent classified as urban. Population density averaged 293 persons per square mile. Average personal per capita income equaled $1,686 compared to $1,832 in Indiana and $1,322 in Kentucky. Two larger cities are located in the area, Henderson, Kentucky and Evansville, Indiana having populations of 16,900 and 141,500 respectively.

Manufacturing is the most important employment category. Establishments employing 100 workers or more increased from 40 in 1958 to 46 in 1964. Vanderburgh County accounted for 39 of the 1964 total establishments. The most important industries are machinery (including electrical machinery); transportation, communication, and utilities; food processing; and fabricated metals. Four thermal power generating plants are located in the area having a total capacity of 167.7 megawatts.

The total value of farm products sold increased from $10.9 million in 1954 to $13.5 million in 1959. All crops accounted for 53 percent of the 1959 figure. Less than 10 acres were irrigated in 1959.

Mining activity is confined mainly to coal and oil extraction. Henderson County produced a relatively small amount of coal in 1960, 301,200 tons, but relatively large amounts of oil, 3.3 million barrels. Although there was no coal produced in Vanderburgh County, some crude oil was extracted but production data are not available.

Minor Area O-3

The O-3 minor area 1960 population was 142,200. Average personal per capita income was $1,399 compared to $1,832 in Indiana and $1,322 in Kentucky. One larger city, Owensboro, Kentucky, is located in the minor area having a population of 42,500.

Manufacturing is the most important employment category. Establishments employing 100 workers or over increased from 22 in 1958 to 30 in 1964. The most important industries are machinery (including electrical machinery); transportation, communication and utilities; furniture and wood products; and food processing. Three thermal power generating plants are located in the minor area having a total capacity of 227.5 megawatts.

During the period 1954-1959, 25,000 acres were taken out of farm production, and the total value of farm products sold increased from $27.9 million to $32.4 million. Approximately 48 percent of the latter figure was accounted for by all crops. Agricultural employment fell from 11,300 in 1950 to 6,100 in 1960. Less than 100 acres were irrigated in 1959.

Coal and crude oil production are the most important mining activities in this minor area. In 1960, the area produced 6.7 million tons of coal, 83 percent of which came from Warrick County in Indiana, representing 43.3 percent of the total coal production in Indiana. The coal produced in the Kentucky counties represented 10.1 percent of the total production in Kentucky. In 1960, the minor area produced 3.1 million barrels of crude oil, the Kentucky counties in the area accounting for 14.6 percent of the total production in Kentucky and the Indiana counties accounting for 25.5 percent of the total Indiana production.

Projected Population and Industrial Activity

The Lower Ohio-Evansville Subarea population is expected to increase from 559,200 in 1960 to 1,035,000 by the year 2020. Whereas the subarea contained 2.9 percent of the total Ohio River Basin population in 1960, it is projected to contain 3 percent by the year 2020. Table 6e shows the base and projected population for O-1, O-2 and O-3 minor areas.

Agricultural output is projected to increase from $208.4 million in 1960 to $305.9 million in the year 2010. Mining output is projected to increase from $184.6 million in 1960 to $1.4 billion by the year 2010.

Manufacturing output is projected to increase from $1.1 billion in 1960 to $5.5 billion by the year 2010. Table 7e shows 1960 output, employment and manufacturing employment. Projections to 1980, 2000 and 2020 for the minor areas are shown as indices using 1960 as the base.

In addition to the counties included in the Lower Ohio-Evansville Subarea in the Projective Economic Study, nine other counties have land areas in the basin. These counties are listed in Table 8e.

V WATER REQUIREMENTS - MUNICIPAL AND INDUSTRIAL

The Ohio River and alluvium along the river constitute major sources of water supply. There are 27 communities that obtain their water supply from the Ohio River. These communities serve a population of about 2,210,000 with an average daily water use of about 277 mgd. In addition, 91 communities obtain their supply from the alluvium or infiltration galleries along the river, serving a population of about 670,000 with an average water use of about 66 mgd. It is estimated that industry along the river uses approximately 1,100 mgd, exclusive of cooling water for thermal power generating plants. The largest industrial water use occurs in the Pittsburgh, Pennsylvania to Portsmouth, Ohio reach of the Ohio River.

For purposes of this study, the main stem was divided into five reaches coinciding for the most part with the subareas defined by the Projective Economic Study. Subarea C, the Pittsburgh S.M.S.A., is included with the Upper Ohio reach.

Ohio River Main Stem-Upper

Present and Projected Water Use

In the upper Ohio River main stem direct drainage and minor tributaries area, there are 115 central water supply systems, serving a population of 884,000. The average daily water use is 86 mgd amounting to 98 gallons per capita daily water use.

Over 55 percent of the total water used for municipal purposes is obtained from ground sources and about 79 percent of the total water used for municipal purposes is obtained from the Ohio River or from ground sources located in the alluvium along the Ohio River. The present (1960) municipal and industrial water use in the basin is listed by county and totaled for economic subareas, minor tributaries and the basin in Table 9a.

The portion of Subarea C draining directly to the Ohio River is located entirely within Pennsylvania. Over 75 percent of municipal supplies in this reach are obtained from ground sources. Of the communities using surface sources, one community using over 56 percent of the water obtains its supply from an impounded upland

source, two communities obtain their supply from the Ohio River and three smaller communities use impounded sources. Larger communities in this reach of the main stem are Bellevue, Aliquippa and Coraopolis served from ground sources and Ambridge served from an impounded upland surface source. In this reach, industrial water use accounting for 35 percent of the total industrial water use in the upper main stem is obtained from the Ohio River or the alluvium.

In minor area E-2, about 67 percent of municipal water supplies are obtained from surface sources. Of the 24.4 mgd obtained from ground sources, 20.7 mgd or about 67 percent is from the Ohio River with the remainder obtained from impounded upland sources. Most of the ground water sources are in the alluvium along the Ohio River. Major communities using the Ohio River as a source of supply are East Liverpool, Ohio; Steubenville, Ohio and Wheeling, West Virginia. Larger communities using ground sources from the alluvium are Martins Ferry, Ohio and Moundsville, West Virginia. Industrial water use in this reach of the main stem accounts for over 41 percent of the industrial water use in the upper Ohio River main stem and supplies are obtained from the Ohio River and alluvium along the river.

In minor area E-1, over 90 percent of the municipal water supplies are obtained from ground sources. The larger communities of Marietta, Ohio, and Parkersburg, West Virginia, account for about 70 percent of the total municipal water use in this reach. Only one supply of less than 0.5 mgd is obtained from the Ohio River. Industrial water use in this minor area accounts for 18 percent of the total industrial water use in the upper Ohio main stem. Supplies are obtained from the Ohio River or from the alluvium along the river.

Located on the larger tributary streams draining into the upper Ohio River main stem are Washington and Canonsburg, Pennsylvania, located on Chartiers Creek; McDonald, Pennsylvania, located on Robinson Run and Athens and Lancaster, Ohio, located in the Hocking River drainage area.

Supplies for communities located on Chartiers Creek and Raccoon Creek are obtained from surface sources. In the Hocking River subbasin, over 80 percent of the water used by municipalities is obtained from ground sources including the supplies for Lancaster and Athens which together account for over 70 percent of the total water use in the subbasin.

Based on population increase and projected industrial activity, estimated water use will increase in the upper Ohio River main stem as shown in Table 10a. It is estimated that total water use will double by 2020. The major increases will probably occur in or about the present centers of population and industrial activity largely along the Ohio River. In the portion of Subarea C tributary to the Ohio River, it is estimated that water use will double, while in minor area E-1 projections indicate an increase of 2.5 times. In minor area E-2, it is projected that water use will about double by 2020. However, in the Hocking River subbasin, increase in water use is projected to be five times the present use.

Water Supply Problems

The projected total water supply figures shown in Table 10a, the minimum day low flow data given in Tables 5a and 5b, and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11a are problem areas with the approximate time of onset of the problem.

In the portion of Subarea C tributary to the Ohio River, total water use is projected to increase to 300 mgd by 1980, to 386 mgd by 2000 and to 535 mgd by 2020. Approximately 90 percent of the projected water use will be for industrial purposes. It is assumed that increased industrial activity will occur in the area along the main stem where ample supplies of surface and ground water are available. The problem for the communities listed in the table is one of expansion of facilities rather than shortage of supply since ample surface water exists in the main stem of the Ohio River and in the alluvium adjacent thereto.

In minor area E-2, total water use is projected to increase to 320 mgd by 1980, to about 383 mgd by 2000 and to 512 mgd by 2020. Approximately 85 percent of the projected water use will be for industrial purposes. It is assumed that increased industrial activity will occur in the area along the main stem where ample ground and surface supplies exist. The communities in minor area E-2 listed in Table 11a, with the exception of Barnesville, East Palestine, Leetonia, Lisbon and Salem, Ohio, are located along the Ohio River and there should not be a shortage of supply that can not

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11a

OHIO RIVER MAIN STEM-UPPER

Direct Drainage and Minor Tributaries
Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
North Fayette Twsp., Pa.	C		X		
Aliquippa, Pa.	C		X		
Monaca, Pa.	C		X		
Belpre, Ohio	E-1		X		
Marietta, Ohio	E-1		X		
New Martinsville, West Virginia	E-1		X		
Paden City, W.Va.	E-1		X		
Parkersburg, W.Va.	E-1		X		
Barnesville, Ohio	E-2		X		
Martins Ferry, Ohio	E-2			X	
Follansbee, W.Va.	E-2		X		
Wellsburg, W.Va.	E-2		X		
East Palestine, Ohio	E-2		X		
Leetonia, Ohio	E-2			X	
Lisbon, Ohio	E-2		X		
Salem, Ohio	E-2		X		
Wellsville, Ohio	E-2			X	
McMechen, W.Va.	E-2			X	
Moundsville, W.Va.	E-2			X	
Athens, Ohio	E-1		X		
Lancaster, Ohio	I-1		X		
New Lexington, Ohio	F-1		X		

be met by expansion of facilities. However, the aforementioned communities of Barnesville, on Captina Creek, and East Palestine, Leetonia, Lisbon and Salem in the Little Beaver River watershed probably will encounter supply problems during periods of peak demands by the dates indicated. Barnesville, located in the headwater of Captina Creek, presently uses a surface source of supply. In the absence of a dependable source of ground water, expansion of existing surface storage will probably be required. East Palestine, Leetonia, and Lisbon presently use ground sources. These communities are

located in areas where the indications are that ground water is of intermediate yield, and their supplies can probably be augmented by expansion. Salem, presently using a surface source, is located in the headwater reach of the Middle Fork of Little Beaver River. The adequacy of local ground water resources as an alternative or supplementary source of water to meet future needs is not presently known and should be studied.

In minor area E-1, total water use is projected to increase to 174 mgd by 1980, to 257 mgd by 2000 and to 347 mgd by 2020. Approximately 93 percent of the projected water use will be for industrial purpose. It is assumed that increased industrial activity will occur in the area along the main stem where ample ground and surface water supplies exist.

By 1980 indications are that Lancaster and Athens, located in the Hocking River subbasin and presently using ground water sources, will need further development of ground or surface water sources to meet their future needs. New Lexington, presently using a surface source, by 2000 will probably experience supply problems during periods of high water use and low runoff. Expansion of existing storage facilities or construction of additional surface storage facilities can be accomplished to meet future needs.

Ohio River Main Stem-Huntington

Present and Projected Water Use

In this portion of the main stem, in areas draining directly to the Ohio River and/or drained by minor tributaries, there are 32 central water supply systems serving a population of 310,000. The average daily water use is 30 mgd amounting to a per capita water use of 95 gpd.

About 84 percent of the total water used for municipal purposes is obtained from surface sources, with about 94 percent of the total municipal water use being obtained from the Ohio River or from wells located in the alluvium along the river. The present municipal and estimated industrial water use in the basin is listed by county and totaled by economic subareas, minor tributaries and the basin in Table 9b.

In minor area H-3, over 58 percent of the water used for municipal purposes is obtained from ground sources. Larger municipalities along the main stem in this area are Gallipolis, Ohio and Point Pleasant, West Virginia, using ground sources, and Middleport and Pomeroy, Ohio, using both wells and the Ohio River as a source of supply. Industrial water use along this reach of the main stem is 24 percent of the total estimated industrial water use in Subarea H and is obtained from the Ohio River or from the alluvium along the river.

In minor area H-2, almost 97 percent of the water used for municipal purposes is obtained from the Ohio River. Major communities in this area are Ashland, Kentucky; Huntington, West Virginia; and Ironton, Ohio, accounting for all of this water use. It should be noted that Catlettsburg, Kentucky, located at the mouth of the Big Sandy River, obtains its supply from this stream and supplies water, in addition to its own needs, to several communities which are a part of the Huntington, West Virginia, S.M.S.A. Industrial water use in this minor area accounts for about 66 percent of the total industrial water use in Subarea H and supplies are obtained from the Ohio River or alluvium adjacent to the river.

In minor area H-1, over 91 percent of the water used for municipal purposes is obtained from surface sources, with one community, Portsmouth, Ohio, accounting for practically all this use. Industrial water use in this minor area accounts for about 10 percent of the total industrial water use in Subarea H.

Larger communities on tributary streams are Wellston, Ohio on Little Raccoon Creek and Olive Hill, Kentucky on Tygarts Creek. Both communities use surface water as the source of supply.

Based on population increase and projected industrial activity, estimated water use is projected to increase in the minor areas as shown in Table 10b. It is estimated that total water use will increase 3.5 times by 2020 in Subarea H. The major increases will probably occur in or about the present centers of population and industrial activity, largely along the Ohio River. In minor area H-3, it is estimated that water use will increase over five times, while in minor area H-2 projections indicate a threefold increase, and in minor area H-1 a fourfold increase is indicated.

Water Supply Problems

The projected total water supply figures shown on Table 10b, the minimum day low flow data given in Tables 5a and 5b, and availability of ground water as reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11b are the problem areas with the approximate time of onset.

TABLE 11b

OHIO RIVER MAIN STEM-HUNTINGTON

Direct Drainage and Minor Tributaries
Water Supply Problem Areas

	Minor Areas	Present	1980	2000	2020
Raceland, Ky.	H-1			X	
Gallipolis, Ohio	H-3		X		
Point Pleasant, W.Va.	H-3		X		

Although water usage is projected to increase appreciably as shown in Table 10b, since most of the water supplies are obtained from the Ohio River or from the alluvium recharged by the river, there should be adequate quantities of water to meet projected needs. The communities listed in Table 11b as problem areas are all located along the Ohio River and use ground sources and can readily solve their problems of supply by expansion or extension of their present systems.

Ohio River Main Stem-Cincinnati

Present and Projected Water Use

In this portion of the main stem, draining directly to the Ohio River and drained by minor tributaries, there are 34 central water supply systems serving a population of 1,029,000. The average daily water use is 121 mgd amounting to a per capita water use of 118 gpd.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

About 94 percent of the total water used for municipal purposes is obtained from surface sources. About 97 percent of the total is obtained either from the Ohio River and from wells located in the alluvium along the river. The estimated present municipal and industrial water use in the basin is listed by county and totaled by economic subareas, minor tributaries and the basin in Table 9c.

In minor area K-3, over 65 percent of the water used for municipal supplies is obtained from surface sources. The largest community using the Ohio River as a source of supply is Maysville, Kentucky. Other communities using surface sources are located in the Ohio counties in the Brush Creek and White Oak Creek drainage areas. Small communities located along the Ohio River use ground sources. Industrial water use is very small in this minor area.

In minor area K-2, practically all water used for municipal purposes is obtained from the Ohio River. Cincinnati has the largest water system, supplying most of Hamilton County and accounting for 89 percent of the water use in the minor area. The communities of Newport and Covington, Kentucky, using Ohio River water, along with Kenton County Water District No. 1 obtaining water from the Licking River, supply most of the northern Kentucky area. Located in the Mill Creek drainage area is most of the heavy manufacturing industry in the Cincinnati area. Water is imported from the Great Miami River Basin to supply a number of these industries. Ground water is still an important source of supply for many of the plants. Three communities serving over 22,000 people use ground water as their source of supply.

In minor area K-1, about 68 percent of the water used for municipal purposes is obtained from ground sources. Sixty-seven percent of the total water used for municipal purposes is obtained from wells located in the alluvium along the Ohio River. The larger communities in this area are Lawrenceburg and Aurora, Indiana. In the Laughery Creek drainage area, located in Indiana, most of the municipal supplies are obtained from surface sources. The largest community in this subbasin is Batesville. Industrial water use in this subarea is located primarily in the Lawrenceburg area and accounts for most of the industrial water use in the subarea.

Based on population increase and projected industrial activity, estimated total water use in Subarea K will increase almost threefold by 2020 as shown in Table 10c. The major increases will probably occur in or about the present centers of population and

industrial activity. It is projected that by 2020 water use will increase in minor area K-3 fourfold, in minor area K-2 the use will be more than doubled and in minor area K-1 the increase will be over 5.5 times. In the Mill Creek drainage area, water use is projected to increase 3.5 times, primarily for industrial use.

Water Supply Problems

The projected total water supply figures shown in Table 10c, the minimum day low flow data given in Tables 5a and 5b, and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11c are problem areas with approximate time of onset.

TABLE 11c

OHIO RIVER MAIN STEM-CINCINNATI

Direct Drainage and Minor Tributaries
Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Greendale, Ind.	K-1		X		
Lawrenceburg, Ind.	K-1		X		
Rising Sun, Ind.	K-1			X	
Batesville, Ind.	K-1		X		
West Union, Ohio	K-3	X			
Georgetown, Ohio	K-3	X			
Lockland, Ohio	K-2		X		
Reading, Ohio	K-2		X		

In minor area K-3, total water use is projected to increase to 4.6 mgd by 2020, with approximately 70 percent of the total water use projected for use as municipal supplies. Communities located

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

along the Ohio River should have no problem in obtaining ample supplies of water, either from the stream or from the alluvium. However, communities located in upland areas draining directly to the Ohio River or on minor tributaries on both sides of the Ohio River will have to rely on surface sources since ground water does not appear to be available in the upland area in sufficient quantities to serve as a source of municipal supply. Indications are that West Union, Ohio, in the Ohio Brush Creek subbasin, should now be planning to augment its present impounded source, since by about 1980 the safe yield will be equaled or exceeded. Alternate solutions, all involving surface storage, could be constructed of a reservoir on a tributary of Ohio Brush Creek or across the ridge in the Eagle Creek Basin. In the White Oak Creek drainage basin, Georgetown is experiencing a shortage in water supply during low flow periods. Georgetown presently pumps water from White Oak Creek into an upland storage reservoir during periods of high to medium flows. Alternate solutions could be expansion of present upland storage capacity or storage in a new reservoir upstream from Georgetown from which water could be released into the streambed and pumped into the upland reservoir.

In minor area K-2, total water use is projected to increase to 160 mgd by 1980, to 208 mgd by 2000 and to 263 mgd by 2020. About 95 percent of this water will be distributed through municipal water supply systems and will be obtained from surface sources primarily from the Ohio River.

Demands for water in the communities of Lockland and Reading, Ohio, in the Mill Creek drainage area will by 1980, probably exceed the capabilities of their existing well fields. A good aquifer, consisting of unconcolidated sand and gravel, occupys an ancestral river valley in this area. Unfortunately, withdrawals for municipal and industrial use continue to exceed the recharge capabilities of the aquifer and the ground water level has had a declining trend. Even if open area did exist to expand the present well fields of the aforementioned communities, ground water levels may decline by 1980 to the point where reliable wells could not be developed. A possible solution to the general ground water problem may be artificial (pumped) recharge of the aquifer with treated surface water. Another possible solution could be connection to a water system having a source outside the drainage area.

In minor area K-1, the communities or Greendale, Lawrenceburg and Rising Sun, Indiana, are all located along the Ohio River. Indications are that facilities will need to be expanded for Greendale and Lawrenceburg by 1980 and Rising Sun by 2000. Supply is obtained from alluvium along the Ohio River and provided the quality of the surface water in the Ohio River is protected so that infiltrated water remains of good quality, ample supplies should be available. Over 85 percent of the projected water supply use in this minor area will be for industrial needs. Since this future need will probably be centered near points of present use along the Ohio River, ample ground water and surface sources are available to meet these needs. Batesville, Indiana, located in the Laughery Creek drainage area, will probably experience water supply problems by 1980. In the absence of a dependable ground water source, reliance must continue to be placed on surface sources. Although Batesville is located in the headwaters area of the subbasin, water storage impoundments can probably be constructed to meet future needs either in the Laughery Creek subbasin or in an adjacent watershed.

Ohio River Main Stem-Louisville

Present and Projected Water Use

In this portion of the main stem, drained directly by the Ohio River and minor tributaries, there are 30 central water supply systems serving a population of 710,000. The average daily water use is 100 mgd, amounting to a per capita water use of 141 gpd.

Over 89 percent of the total water used for municipal purposes is obtained from surface sources, with about 98 percent of the total supply obtained either from the Ohio River or from wells located in the alluvium along the river. The estimated present municipal and industrial water use in the basin is listed by county and totaled by economic subareas, minor tributaries and the basin in Table 9d.

In minor area N-3, all of the water for municipal supplies is obtained from ground sources from wells located in the alluvium along the Ohio River. The largest community in this minor area is Madison, Indiana, accounting for almost 91 percent of the water use. Industrial water use is small, accounting for about five percent of the total industrial water use in the subarea.

In minor area N-2, about 93 percent of the water for municipal supplies is obtained from surface sources, primarily from the Ohio River. Louisville, Kentucky, using the Ohio River as its source, accounts for over 88 percent of the total municipal water use in the minor area. The urbanized area of Louisville, Kentucky, which includes Jeffersonville, New Albany, and Clarksville, Indiana, accounts for over 98 percent of the water use in this minor area. Industrial water use amounting to 91 percent of the total industrial water use in Subarea N occurs in this minor area.

In minor area N-1, there are no large communities and water use is about evenly divided between ground and surface sources. There is no appreciable use of water for industrial purposes.

The largest tributary stream in the minor area is the Blue River draining portions of six Indiana counties. However, there are only three central water supply systems in the drainage area serving about 7,400 persons.

Based on population increase and projected industrial activity, estimated total water use will increase in the subarea to over 3.5 times the present use by 2020 as shown in Table 10d. The major increases will probably occur in or about the Louisville, Kentucky S.M.S.A., the present center of population and industrial activity in the subarea. Increase in water use as projected, varies from eightfold in minor area N-1, to over three and one-half fold in minor area N-2, and six and one-half fold in minor area N-3. A sevenfold increase is projected for the Blue River drainage area. It is projected that water use in N-2 by 2020 will account for over 86 percent of the total water use in Subarea N.

Water Supply Problems

The projected total water supply figures shown in Table 10d, the minimum day low flow data given in Table 5a and 5b and availability of ground water as reported by the U. S. Geological Survey[1/] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11d are problem areas with approximate time of onset.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11d

OHIO RIVER MAIN STEM-LOUISVILLE

Direct Drainage and Minor Tributaries
Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Corydon, Ind.	N-1	X			
Charlestown, Ind.	N-2		X		
Jeffersonville, Ind.	N-2	X			
Madison, Ind.	N-3	X			
Salem, Ind.	Q-2	X			

In minor area N-3, total water use is projected to increase to 11.4 mgd by 1980, to 18 mgd by 2000 and to 35 mgd by 2020. About 55 percent of the projected water use will be for minicipal purposes. Indications are that Madison, Indiana, using ground sources, presently needs to expand its supply facilities. However, ample ground water is available in the alluvium along the Ohio River to meet projected needs.

In minor area N-2, total water use is projected to increase to 208 mgd by 1980, to 300 mgd by 2000 and to about 416 mgd by 2020. About 65 percent of the projected water use will be for municipal purposes. It is assumed that increased industrial activity will occur in the area along the main stem, where there are ample supplies of ground and surface water available. Surface water is presently used as a source of supply by Louisville, Kentucky, who probably will continue to use this source. However, due to increased population and industrial activity upstream, problems of taste and odor will probably increase. The desirability of recharging Ohio River water to the alluvial deposits and obtaining supplies from wells should be investigated.

The communities of Jeffersonville and Charlestown, Indiana presently use ground sources. Their problem can be solved by expansion of well fields, since ample supplies of ground water are present in the alluvium along the Ohio River.

Projected water use in minor area N-1 is relatively modest with total water use projected to increase to 5 mgd by 1980, to 9 mgd by 2000 and to 17 mgd by 2020. Much of this increase will probably occur along the Ohio River where ample ground and surface supplies are available. The community of Corydon, Indiana, located in the Big Indian Creek subbasin, uses surface sources for supply, presently needs to develop additional supply sources, probably a local impoundment.

Salem, Indiana, located in the headwaters region of the Blue River drainage area, presently need to develop additional surface storage to meet increased needs.

Ohio River Main Stem-Evansville

Present and Projected Water Use

In this portion of the main stem, drained directly by the Ohio River and minor tributaries, there are 56 central water supply systems serving a population of 403,000. The average daily water use is 46 mgd amounting to a per capita water use of 114 gpd.

Over 77 percent of the total water used for municipal purposes is obtained from surface sources, while over 91 percent of the total water is obtained either from the Ohio River or from wells located in the alluvium along the river. The estimated present municipal and industrial water use in the basin is listed by county and totaled by economic subareas, minor tributaries and the basin in Table 9e.

In minor area O-3, practically all water developed for municipal use is obtained from ground sources, mostly from the alluvium along the Ohio River. The largest community in this minor area is Owensboro, Kentucky. Approximately 33 percent of the industrial water use in the subarea is developed in this minor area.

In minor area O-2, the communities of Evansville, Indiana and Hendersonville, Kentucky, use the Ohio River directly as a source of supply and account for practically all the municipal water use. Evansville, Indiana, alone accounts for 88 percent of the total water use. Almost 51 percent of the industrial water use in the subarea occurs in this minor area.

In minor area 0-1, over 80 percent of the municipal water use is developed from surface sources. Paducah, Kentucky, the largest community in this minor area, using the Ohio River as a source of supply, accounts for over 56 percent of the total municipal water use. Over 92 percent of all water used for municipal purposes is obtained either from the Ohio River or the alluvium along the Ohio River. Industrial water use in this minor area accounts for 13 percent of the total industrial water use in the subarea.

In other areas not included in the Projective Economic Study, Cairo, Illinois, is the largest community, serving 9,200 people from a supply obtained from the Ohio River.

Larger minor tributaries in this subarea are the Tradewater River, draining portions of six Kentucky counties and the Saline River draining portions of eight Illinois counties. The largest community in the Tradewater River drainage area is Providence, accounting for about 40 percent of the water use in the subbasin. In the Saline River subbasin, the largest community is Harrisburg, accounting for over 42 percent of the municipal water use in this subbasin. There is very little water used for industrial purposes in these two subbasins.

Based on population increase and projected industrial activity, estimated total water use in Subarea O will increase almost fourfold by 2020. Water use is projected to increase 4.5 times in minor area O-3, 3.5 times in minor area O-2, to 3.5 times in minor area O-1, and in other areas in the basin an increase of 3.5 times is projected. Increases in water use by 2020 in the Tradewater River drainage area are projected to be about six times the present use and in the Saline River drainage area by 2020, about 3.5 times the present use. Over 50 percent of industrial water use in the subarea by 2020 will be needed in minor area O-2.

Water Supply Problems

The projected total water supply figures shown in Table 10e, the minimum day low flow data given in Tables 5a and 5b, and availability of ground water as reported by the U. S. Geological Survey[1] were used to arrive at a judgment as to need of future development of sources of water supply. Shown in Table 11e are problem areas with approximate time of onset.

1/ Ground-Water Distribution and Potential in the Ohio River Basin, Appendix E, Ohio River Basin Comprehensive Survey.

TABLE 11e

OHIO RIVER MAIN STEM-EVANSVILLE

Direct Drainage and Minor Tributaries
Water Supply Problem Areas

	Minor Area	Present	1980	2000	2020
Owensboro, Ky.	0-3		X		
Tell City, Ind.	0-3	X			
Boonville, Ind.	0-3		X		
McLeansboro, Ill.	R-1		X		
Harrisburg, Ill.	0-1		X		
Eldorado, Ill.	0-1		X		
Providence, Ky.	0-1	X			

In minor area 0-3, total water use is expected to increase to 31 mgd by 1980, to 50 mgd by 2000 and to 73 mgd by 2020. Over 50 percent of the projected water use will be for municipal purposes. It is assumed that increased industrial activity will occur in the area along the main stem where ample supplies of ground and surface water will be available. Indications are that Tell City, Indiana, and Owensboro, Kentucky, obtaining water from the alluvium along the Ohio River, will need to expand their well fields at the present time and 1980 respectively. Boonville, Indiana, located in an upland area, obtaining its water supply from wells, presently needs to expand its well fields. The aquifer which underlies the area is classified by the U.S. Geological Survey as an intermediate yielding source. However, ample supplies are available in the alluvium along the Ohio River and expansion of well fields in this aquifer will meet future needs.

In minor area 0-2, most of the present supply for Evansville, Indiana, and Henderson, Kentucky, are obtained from the Ohio River. Surface sources are adequate to meet all future foreseeable municipal and industrial needs, providing the quality of the water is protected by adequate quality control measures at upstream points.

In minor area 0-1, total water use is projected to increase to 38 mgd by 2020. As most of the present needs are satisfied from the Ohio River or wells in the alluvium, water appears to be in ample supply.

In the Saline River subbasin, indications are that by 1980, Harrisburg and Eldorado, Illinois, will need to plan for additional sources of supply. Presently, both communities rely on impounded surface sources which could be expanded or as an alternative new impoundments could be developed to meet future needs.

In the Tradewater River subbasin, Providence, Kentucky obtains its water supply from impoundments and uses the Tradewater River as an emergency source. Due to limited firm yield from the impoundments and river, additional supply development is needed, with additional impoundment the most probable solution. Bedrock sources in this area are rated by the U. S. Geological Survey as intermediate yielding sources. With projected water needs, it may become increasingly difficult to obtain enough water from ground sources to meet these needs and it may become necessary to develop surface impoundments to augment these sources.

VI WATER QUALITY CONTROL

The major areas of organic waste discharges occur in the main stem of the Ohio River below Pittsburgh, Pennsylvania and Cincinnati, Ohio. There are many other points of large organic waste discharges such as below Huntington, West Virginia; Louisville, Kentucky and Evansville, Indiana, if flow needs can be met at Pittsburgh and Cincinnati there will be sufficient flow in the river to assimilate residual wastes remaining after secondary treatment at other points of discharge.

Unsatisfactory stream conditions due to insufficient assimilative capacity exist during low flow in a number of tributary streams, notably Chartiers Creek below Washington and Canonsburg, Pennsylvania; in the Hocking River below Lancaster, Ohio; in the Mill Creek at Cincinnati, Ohio and the Saline River below Harrisburg, Illinois. Mine drainage affects many tributary streams in the upper reach of the main stem and also affects the lower reaches of the Saline and Tradewater Rivers in the lower main stem area.

The main stem, for the purposes of this study was divided into five reaches, coinciding for the most part with the subareas defined by the Projective Economic Study. Since waste loads from Pittsburgh enter the Ohio River main stem, Subarea C is included with the upper Ohio River reach.

Ohio River Main Stem-Upper

Present and Projected Waste Loads

Present (1960) organic waste loads generated are shown in Table 12a. The major single source of organic waste discharges in this reach is from the Allegheny County Sanitary Authority. Residual organics are discharged from its treatment plant to the Ohio River at a point just below the confluence of the Allegheny and Monongahela Rivers. Major discharge of industrial organic wastes occurs in Allegheny County either through the aforementioned system or other outfalls. In this area, inorganic discharges from the basic steel and metal finishing industries constitute major inorganic waste sources.

Principal tributaries entering this reach of stream in addition to the Allegheny and Monongahela are the Beaver and Muskingum Rivers.

In the minor tributary basins, residual organic waste loads are discharged to Chartiers Creek by the communities of Washington and Canonsburg, Pennsylvania, to the Little Beaver River by the community of Salem, Ohio, and to the Hocking River by the communities of Lancaster, Logan and Athens, Ohio.

Shown in Table 13a are the base and projected waste loads generated before treatment for minor areas and minor tributaries. Total organic waste loads in the subarea are projected to increase less than 2 times by 2020. Waste loads in minor areas C and E-2 are projected to increase over 1.5 times, while in minor area E-1 the increase is projected to be about 2.5 times by 2020. Waste loads generated in the Chartiers Creek subbasin and Raccoon Creek subbasin are projected to increase about 50 percent by 2020, while in the Hocking River subbasin an increase of 4.5 times is indicated by 2020.

Water Quality Control Problems

Listed in Table 14a are the areas and the approximate beginning date where problems are expected during low flow periods. This table indicates the need for stream flow regulation for quality control after secondary treatment or other appropriate measures for pollution control.

In the main stem, the major quality control problem occurs below the Allegheny County Sanitary Authority sewage treatment plant outfall. At present, primary treatment facilities are operated by the Authority. In addition, residual organic wastes from sewage treatment plants located on the Allegheny and Monongahela Rivers and streams tributary to these rivers are present in these streams when they join to form the Ohio River. While secondary treatment of collectable wastes is assumed, organic wastes enter the streams in the greater Pittsburgh area from the Monongahela, the Allegheny, from overflows from combined sewers and in-street washings. Total flow in the order of 5,000 cfs is needed at the present to assimilate residual waste loads. These needs will increase to 5,700 cfs by 1980, to 6,600 cfs by 2000 and to 7,800 cfs by 2020. The natural low flow, 30 consecutive day average discharge, 10 year frequency, is in the order of 2,400 cfs. After completion of construction of the Corps of Engineers "Group A"[1/] reservoirs, the regulated flow on the above basis will be in the order of 5,600 cfs.

1/ Hydrology of the Ohio River Basin, Appendix C, Ohio River Basin Comprehensive Survey.

TABLE 14a

OHIO RIVER MAIN STEM-UPPER

Direct Drainage and Minor Tributaries
Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Ohio River-Main Stem	Pittsburgh, Pa.	C	X			
Robinson Run	McDonald, Pa.	C	X			
Chartiers Creek	Washington, Pa.	C	X			
Chartiers Creek	Canonsburg, Pa.	C	X			
Little Beaver R. Middle Fork	Salem, Ohio	E-2	X			
Hocking River	Lancaster, Ohio	I-1	X			
Hocking River	Logan, Ohio	I-1	X			
Hocking River	Athens, Ohio	E-1	X			

In the Hocking River subbasin, indications are that the design flow of about 25 cfs is not sufficient to assimilate residual organic waste from the treatment plant in the Lancaster, Ohio area. Flows in the order of 30 cfs are required at the present, increasing to 35 cfs by 1980, to 47 cfs by 2000 and to 55 cfs by 2020. Provision of these flows at Lancaster will maintain satisfactory stream conditions at Logan and Athens after secondary treatment of all organic wastes.

In minor tributaries, unsatisfactory stream conditions exist in Chartiers Creek in the vicinity of Washington and Canonsburg, Pennsylvania, where design flow is very low. Flows in the order of 40 cfs are required at the present (1960) increasing to 50 cfs by 1980, to 60 cfs by 2000 and to 75 cfs by 2020. Provision of the above flows at Washington would maintain satisfactory conditions at Canonsburg. However, as Washington and Canonsburg are located in the headwaters region of the Chartiers Creek drainage basin and storage for the quantity required does not appear to be available, an alternate solution to flow regulation for quality control would be transmission of treatment plant effluent to a larger body of water.

In the Little Beaver River below Salem, Ohio, design flow is negligible. Flows in the order of 15 cfs are required at the present increasing to 22 cfs by 2020.

There are undoubtedly other small tributaries adversely affected by discharge of residual wastes remaining after secondary treatment, but it is beyond the scope of this report to define them all.

Other present or potential quality problems are heat, inorganic discharges and mine drainage. Major sources of heat release to the main stem occur at thermal power plants. In Allegheny and Beaver Counties in Pennsylvania, in Columbiana, Jefferson, Belmont and Washington Counties in Ohio, and in Hancock, Brooke, Marshall, Wetzel, Pleasants and Wood Counties in West Virginia. In the Pennsylvania counties, thermal power generating plants with capacities of 180, 57, 100, 315, and 100 megawatts use surface water for cooling purposes in this reach of stream. Located in the Ohio counties are plants with capacities of 740, 315.8, 222.2, 544 and 160 megawatts, while located in the West Virginia counties there are plants with capacities of 108.3, 300, 450, 225, 54, 215 and 30.8 megawatts. In the Hocking River tributary basin, at Athens, Ohio, a plant with a capacity of 232 megawatts uses ground sources for makeup water for a closed cooling system. In the main stem, although power production is projected to increase fourfold by 1980, there should be ample cooling water providing plants are spaced to allow the stream to recover from the effects of the heat discharged from upstream plants.

Processing in the basic steel and metal finishing industries results in discharges of iron, phenols, and plating wastes which do not necessarily exert a demand on the oxygen resources of the stream, but impart hardness, iron, and taste to the water and affect the use and degree of treatment required by downstream users.

Mine drainage from bituminous coal mining operations affects the main stem and many minor tributary streams in this reach. In Pennsylvania, Raccoon Creek and its tributaries, Montour Run and its tributaries, and Chartiers Creek and its tributaries are adversely affected by mine drainage. In Ohio, the main stem tributaries of Brush Creek, Captina Creek, Kyger Creek, Leading Creek, Yellow Creek and Shade River are among the direct drainage tributary streams adversely affected by mine drainage. In the Hocking River subbasin, the tributary streams of Little Rush Creek, Monday Creek and Sunday Creek are among those affected by mine drainage. In West Virginia, many direct drainage tributaries are affected.

Ohio River Main Stem-Huntington.

Present and Projected Waste Loads

Present organic waste loads generated before treatment are shown in Table 12b. The largest single source of organic waste discharge in this reach is from Huntington, West Virginia, accounting for about one-third of the total organic wastes generated in this reach of stream.

Principal tributaries entering this reach of stream are the Kanawha, Guyandotte, Big Sandy and the Scioto Rivers. Of these tributaries, the Kanawha River in its present state carries the largest load of residual organics and inorganic wastes resulting from the chemical industry located in and around Charleston, West Virginia.

In the minor tributary basins, the largest organic waste source is Wellston, Ohio, located on Little Raccoon Creek.

Shown in Table 13b are the base and projected waste loads generated before treatment for minor areas and minor tributaries. Total organic waste loads are projected to increase about 2.5 times by 2020. Minor area H-2 is projected to increase slightly less than the rate for the total area, while minor areas H-1 and H-3 are projected to increase slightly more than the total area. Organic waste loads are projected to increase in the minor tributaries at about the same rates as the total area.

Water Quality Control Problems

In the main stem, flows supplied to maintain satisfactory dissolved oxygen conditions in the Upper Ohio reach of the stream should maintain satisfactory dissolved oxygen stream conditions throughout the Huntington reach. This does not mean, however, that taste and odor problems will not occur. Phenol and iron wastes discharged to the streams from the basic steel industry upstream, residual organic wastes and algal growths promoted by the inorganic nitrates and phosphates from upstream sources can cause serious taste and odor problems for communities using the Ohio River as a raw water source.

Listed in Table 14b are the areas and the approximate beginning date where problems are expected during low flow periods. The table indicates need for stream flow regulation for quality control after secondary treatment or other appropriate measures for pollution control.

TABLE 14b

OHIO RIVER MAIN STEM-HUNTINGTON

Direct Drainage and Minor Tributaries
Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date			
			Present	1980	2000	2020
Little Raccoon Creek	Wellston, Ohio	H-3	X			

In the minor tributary basins, Little Raccoon Creek at Wellston, Ohio, where design flow is less than 5 cfs, flows in the order of 7 cfs are needed at the present, increasing to 15 cfs by 2020.

There are undoubtedly other small tributaries adversely affected by discharge of residual wastes remaining after secondary treatment, but it is beyond the scope of this report to define all of them.

Other present or potential quality problems are heat, inorganic discharges and mine drainage. Major sources of heat release to the main stem from thermal power generating plants occur in Gallia County, Ohio and Mason County, West Virginia, where plants with capacities of 1,086.3 and 1,060 megawatts respectively, use surface water from the Ohio River for cooling purposes. These plants are located in the same navigation pool (Gallipolis) and during periods of lower flows could have the effect of raising stream temperatures, but at the present this is not a serious problem.

Inorganic discharges are from the basic steel and metal finishing industries and chemical industry plants located along this reach of the main stem. Streams affected by mine drainage in Ohio are Raccoon Creek and tributary streams which drain into Lake Alma and Lake Hope located in the watershed. Many direct drainage tributary streams in West Virginia are also subject to mine drainage discharges.

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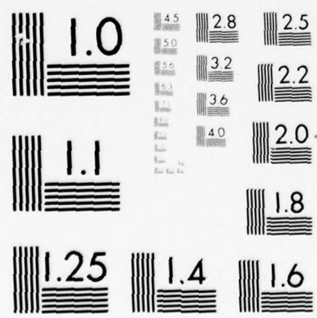


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Ohio River Main Stem-Cincinnati

Present and Projected Waste Loads

Present organic waste generated before treatment is shown in Table 12c. Major organic waste discharges are located in minor area K-2, primarily from Cincinnati, Ohio, and from the Campbell-Kenton County Sanitary District No. 1. These sources account for over 95 percent of the total organic waste generated in Subarea K.

Principal tributaries entering this reach of stream are the Little Miami River, Licking River and Great Miami River, with all confluences located within the K-2 minor area.

Mill Creek, a minor tributary entering the Ohio River at Cincinnati, Ohio, carries a heavy load of organic waste. This stream drains a large portion of the Cincinnati area and a large number of organic waste producing industries are located in the watershed. However, most of the waste entering the stream results from overflow from combined sewers, street washings and effluent from residential septic tanks.

Shown in Table 13c are the base and projected waste loads generated before treatment for minor areas and the minor tributary stream. Waste loads are projected to increase almost threefold by 2020.

Water Quality Control Problems

Listed in Table 14c are the areas and the approximate beginning date where problems are expected during low flow periods. The table indicates the need for stream flow regulation for quality control after secondary treatment or other appropriate measures for pollution control.

In this main stem reach, the major quality problem occurs in the Cincinnati, Ohio area, where outfalls from major sewer treatment plants in Cincinnati and northern Kentucky discharge to the Ohio River. At present, these facilities give primary treatment to organic wastes and during low flow periods, intermediate (chemical) treatment is added to increase removal of the collectable organic wastes. The natural 30 day average 10 year frequency low flow is 6,200 cfs. Assuming secondary treatment, a flow of 8,000 cfs should maintain satisfactory stream conditions below Cincinnati. However, by 1980, due to projected increased residual organic waste discharges, flow needed will increase to about 11,000 cfs. By 2000, the flow needed will increase to about 12,400 cfs and by 2020 to 13,200 cfs.

TABLE 14c

OHIO RIVER MAIN STEM-CINCINNATI

Direct Drainage and Minor Tributaries
Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Ohio River-Main Stem	Cincinnati, Ohio	K-2	X			
Mill Creek	Cincinnati, Ohio	K-2	X			
Laughery Creek	Batesville, Ind.	K-1	X			

In the Mill Creek subbasin, there is one municipal sewage treatment plant located in the upper basin. The problem in this basin, however, is not caused by insufficient assimilative capacity in the stream but rather due to flows from overloaded sanitary sewers and overflow from combined sewers. The solution to this problem is construction of adequate sanitary sewers to handle sewage from the watershed.

In minor tributary basins, summer design flows in Laughery Creek below Batesville, Indiana are less than 5 cfs. Flows in the order of 10 cfs are needed at the present increasing to 15 cfs by 1980, to 20 cfs by 2000 and to 25 cfs by 2020. There are undoubtedly other small tributaries in this subarea especially in the Cincinnati Standard Metropolitan Statistical Area, that are adversely affected by discharges from sewage treatment plants of residual wastes remaining after secondary treatment, and also discharges from residential septic tanks. It is beyond the scope of this report to define them all.

A potential quality problem is related to heat entering with cooling water discharges from thermal power plants. Major sources of heat release to the main stem from thermal power generating plants are in Clermont and Hamilton Counties in Ohio and Dearborn County in Indiana. The plant located in Clermont County will have a capacity of about 1,200 megawatts by 1968 while the two

located in Hamilton County have capacities of 224.3 and 539.2 megawatts. In Dearborn County, Indiana, the plant has been recently expanded to a capacity of about 1,100 megawatts. While these plants are all located in the same navigation pool (Markland), the problems associated with heat discharges have not reached critical proportions. However, careful consideration should be given to locating plants downstream from Cincinnati because of the adverse affects of higher stream temperatures on dissolved oxygen in the stream and increased deoxygenation rates.

Ohio River Main Stem-Louisville

Present and Projected Waste Loads

Present organic waste loads generated before treatment are shown in Table 12d. Major organic waste discharges occur in minor area N-2, primarily from Louisville, Kentucky, and the Indiana cities of New Albany and Jeffersonville located across the Ohio River from Louisville.

Principal tributaries entering this reach of stream are the Kentucky and Salt Rivers. One of the larger minor tributaries is the Blue River. Sizeable organic waste loads are discharged to Indian Creek by the community of Corydon, Indiana. Many small tributaries in the Louisville, Kentucky area also receive sizeable residual organic waste loads from sewage treatment plants.

Shown in Table 13d are the base and projected organic waste loads generated before treatment for minor areas and minor tributaries. Waste loads generated are projected to increase over fourfold in this reach by 2020. Increases in the order of seven times are projected for minor areas N-1 and N-3 and in the Blue River minor tributary basin, while minor area N-2 is projected to increase just slightly below the average increase for the subarea.

Water Quality Control Problems

Listed in Table 14d are the areas and the approximate beginning date where problems are expected during low flow periods. The table indicates the need for stream flow regulation for quality control after secondary treatment or other appropriate measures for pollution control.

TABLE 14d

OHIO RIVER MAIN STEM-LOUISVILLE

Direct Drainage and Minor Tributaries
Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Big Indian Creek	Corydon, Ind.	N-1	X			
Blue River	Salem, Ind.	Q-2	X 1/			

In the main stem, if flows are supplied upstream at Cincinnati to maintain satisfactory stream conditions, satisfactory conditions will be maintained below Louisville, Kentucky.

In the minor tributary basins, problems could occur in the Blue River below Salem, Indiana with design flow of less than 5 cfs. At present, flow in the order of 6 cfs is indicated after secondary treatment, increasing to 12 cfs in 1980, to 20 cfs in 2000 and to 30 cfs in 2020. Since Salem is located in the headwaters region, storage of water for purpose of water quality control does not appear to be a feasible solution to this problem. It may be that holding ponds used for "polishing" sewage plant effluent and for discharge during periods of higher natural flow would be a feasible solution.

Stream conditions in Big Indian Creek below Corydon, Indiana are unsatisfactory at present. This stream has a negligible design flow, and flows in the order of 9 cfs are needed at present, increasing to 15 cfs by 1980, to 20 cfs by 2000 and to 28 cfs by 2020.

Many minor tributary streams in the greater Louisville, Kentucky area have unsatisfactory conditions. Solution to these problems in a major metropolitan area, located near a major body of water, is not low flow regulation in the smaller streams, but rather, improved collection and transmission of treated effluent to the larger body of water.

1/ Salem has initiated improvement to its sewage treatment plant.

A potential quality problem is heat. Major sources of heat release to the main stem occurs in Jefferson and Floyd Counties in Indiana, where plants with capacities of 1,304 MW and 660 MW are located and in Jefferson County, Kentucky where plants with capacities of 50 MW, 337.5 MW and 715.3 MW are located. These plants use surface water for cooling purposes, but sufficient flows appear to be available in the stream to maintain temperatures within safe limits. In a minor tributary basin, Pleasant Run in Jefferson County, Indiana, a plant is located with a capacity of 50 MW.

Ohio River Main Stem-Evansville

Present and Projected Waste Loads

Present organic waste loads generated before treatment are shown in Table 12e. Major organic waste discharges are located in minor area 0-2, primarily from the Evansville, Indiana area, accounting for almost 50 percent of the total organic waste loads discharged to the streams in subarea 0.

Principal tributaries entering the reach of stream are the Green, Wabash, Cumberland, and Tennessee Rivers. Minor tributaries are the Tradewater and Saline Rivers.

Shown in Table 13e are the base and projected organic waste loads generated before treatment for minor areas and minor tributaries. Waste loads generated are projected to increase about 3.5 times in this reach by 2020. Increase in the order of 2.5 times is projected for minor area 0-1, 3.5 times for minor area 0-2, and four times for minor area 0-3. Waste loads in the Saline River Basin and the Tradewater River Basin are projected to double by 2020.

Water Quality Control Problems

Listed in Table 14e are the areas and the approximate beginning date where problems are expected during low flow periods. The table indicates the need for stream flow regulation for quality control after secondary treatment or other appropriate measures for pollution control.

TABLE 14e

OHIO RIVER MAIN STEM-EVANSVILLE

Direct Drainage and Minor Tributaries
Present and Projected Water Quality Control Problem Areas

Stream	Vicinity	Economic Area	Approximate Beginning Date Present	1980	2000	2020
Saline River	Harrisburg, Ill.	O-1	X			

In the main stem, there is no apparent need for streamflow over and above that provided upstream at Cincinnati, Ohio, in order to maintain satisfactory stream conditions in the main stem.

The Saline River below Harrisburg, Illinois has a design flow of less than 5 cfs. Presently Harrisburg has secondary treatment. Indications are that flows in the order of 15 cfs are needed now, increasing to 20 cfs by 1980, to 28 cfs by 2000 and to 35 cfs by 2020 to assimilate effluent from secondary treatment. There are undoubtedly other small tributaries adversely affected by discharge of residual wastes remaining after secondary treatment, but it is beyond the scope of this report to define all of them.

Other present or potential quality problems are heat and mine drainage. Major sources of heat release to the main stem are from thermal power generating plants located in Warrick County, Indiana, with capacities of 143 and 125 MW; in Vanderburgh County, Indiana, with capacities of 22.2 and 121.5 MW; in Daviess County, Kentucky, a plant with a capacity of 203.5 MW; in Henderson County, Kentucky, a plant with a capacity of 25 MW; in McCracken County, Kentucky, a plant with a capacity of 1,500 MW and in Massac County, Illinois, a plant with a capacity of 1,100.3 MW. Sufficient flows in the Ohio River appear to be available to maintain stream temperatures within safe limits.

Mine drainage adversely affect portions of the Saline and Tradewater Rivers and their tributaries and the direct drainage tributaries of Pup Creek and Blackford Creek. The Saline River is in Illinois; the remaining streams are in Kentucky.

A problem recently developed involves pH values greater than 9.0. The high alkalinity problem appears to be related to the chemical industry below Louisville, Kentucky.

TABLES

TABLE 1a

OHIO RIVER MAIN STEM-UPPER

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Direct Drainage			
Pennsylvania		Allegheny	22.4
Ohio	*	Athens	17.5
Pennsylvania		Beaver	51.3
Ohio	*	Belmont	80.0
West Virginia	*	Brooke	100.0
Pennsylvania		Butler	0.2
Ohio		Carroll	20.0
"	*	Columbiana	83.4
Pennsylvania		Greene	6.4
West Virginia	*	Hancock	100.0
Ohio		Harrison	27.7
"	*	Jefferson	100.0
Pennsylvania		Lawrence	10.4
Ohio		Mahoning	17.8
West Virginia	*	Marshall	78.2
Ohio	*	Monroe	90.8
"		Noble	44.3
West Virginia	*	Ohio	37.4
" "	*	Pleasants	55.2
" "	*	Tyler	7.6

TABLE 1a (cont'd)

OHIO RIVER MAIN STEM-UPPER

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Ohio	*	Washington	63.0
Pennsylvania		Washington	24.7
West Virginia	*	Wetzel	98.7
" "	*	Wood	45.9
Tributaries			
Chartiers Creek			
Pennsylvania		Allegheny	11.7
"		Washington	21.4
Raccoon Creek (in Pennsylvania)			
Pennsylvania		Allegheny	2.3
"		Beaver	21.0
"		Washington	8.3
Wheeling Creek			
Pennsylvania		Greene	14.9
West Virginia	*	Marshall	21.8
" "	*	Ohio	62.6
Pennsylvania		Washington	8.8

TABLE 1a (cont'd)

OHIO RIVER MAIN STEM-UPPER

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Middle Island Creek			
West Virginia	*	Doddridge	79.7
" "	*	Pleasants	44.8
" "	*	Tyler	92.4
" "	*	Wetzel	1.3
Hocking River			
Ohio	*	Athens	74.2
"		Fairfield	56.4
"		Hocking	52.7
"		Morgan	15.1
"		Perry	57.9
"	*	Washington	3.1

*Counties considered in economic projections of Ohio River Main Stem-Upper.

TABLE 1b

OHIO RIVER MAIN STEM-HUNTINGTON

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Direct Drainage			
Kentucky	*	Boyd	20.2
West Virginia	*	Cabell	29.6
Ohio	*	Gallia	61.7
Kentucky	*	Greenup	20.9
Ohio		Hocking	0.0
"	*	Jackson	38.3
West Virginia	*	Jackson	84.7
Ohio	*	Lawrence	100.0
Kentucky	*	Lewis	92.0
West Virginia	*	Mason	53.2
Ohio	*	Meigs	96.7
"	*	Pike	9.6
West Virginia		Putnam	1.0
" "		Roane	8.5
Ohio	*	Scioto	59.7
"	*	Vinton	0.0
West Virginia	*	Wayne	3.5
" "		Wirt	0.9

TABLE 1b (cont'd)

OHIO RIVER MAIN STEM-HUNTINGTON

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Tributaries			
Ohio-Racoon Creek			
Ohio		Athens	7.5
"	*	Gallia	38.3
"		Hocking	11.0
"	*	Jackson	23.2
"	*	Meigs	3.3
"	*	Vinton	70.8
Twelvepole Creek			
West Virginia	*	Cabell	1.8
" "		Lincoln	3.2
" "		Mingo	12.6
" "	*	Wayne	73.1
Tygart Creek			
Kentucky		Carter	41.9
"	*	Greenup	43.8

*Counties considered in economic projections of Ohio River Main Stem-Huntington.

TABLE 1c

OHIO RIVER MAIN STEM-CINCINNATI

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Ohio	*	Adams	77.0
Kentucky	*	Boone	96.4
"	*	Bracken	55.9
Ohio	*	Brown	74.4
Kentucky	*	Campbell	56.2
Ohio	*	Clermont	34.0
Indiana	*	Dearborn	84.5
"		Decatur	4.0
"		Franklin	4.0
Kentucky	*	Gallatin	63.8
Ohio	*	Hamilton	16.4
"		Highland	41.8
Kentucky	*	Kenton	13.5
"	*	Mason	38.4
Indiana	*	Ohio	100.0
Kentucky		Pendleton	8.6
Indiana	*	Ripley	62.7
Ohio		Ross	0.2
Indiana	*	Switzerland	100.0

TABLE 1c (cont'd)

OHIO RIVER MAIN STEM-CINCINNATI

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Tributaries			
Mill Creek			
Ohio		Butler	10.2
"	*	Hamilton	27.1

*Counties considered in economic projections of Ohio River Main Stem-Cincinnati.

TABLE 1d

OHIO RIVER MAIN STEM-LOUISVILLE

Direct Drainage and Minor Tributaries
Counties in Basin

State Direct Drainage		County	Percent of Land Area in Basin
Kentucky	*	Breckinridge	60.3
"	*	Bullitt	1.6
"	*	Carroll	36.5
Indiana	*	Clark	95.4
"	*	Crawford	58.4
"	*	Floyd	87.7
Kentucky		Hardin	18.2
Indiana	*	Harrison	66.9
Kentucky		Henry	4.4
Indiana	*	Jefferson	49.2
Kentucky	*	Jefferson	68.7
"	*	Meade	100.0
"	*	Oldham	69.4
Indiana		Scott	8.2
Kentucky	*	Trimble	77.0
Indiana		Washington	1.4

TABLE 1d (cont'd)

OHIO RIVER MAIN STEM-LOUISVILLE

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Tributaries			
Blue River			
Indiana	*	Clark	4.2
"	*	Crawford	22.7
"	*	Floyd	12.3
"	*	Harrison	23.1
"		Orange	2.8
"		Washington	53.2

*Counties considered in economic projections of Ohio River Main Stem-Louisville.

TABLE 1e

OHIO RIVER MAIN STEM-EVANSVILLE

Direct Drainage and Minor Tributaries
Counties In Basin

State		County	Percent of Land Area in Basin
Direct Drainage			
Illinois		Alexander	48.1
Kentucky	*	Ballard	56.3
"	*	Caldwell	0.0
"	*	Crittenden	55.2
"	*	Daviess	28.8
Indiana		Du Bois	11.6
Illinois	*	Gallatin	7.9
Indiana		Gibson	29.2
Kentucky	*	Hancock	85.3
Illinois	*	Hardin	79.7
Kentucky	*	Henderson	65.3
Illinois	*	Johnson	80.7
Kentucky	*	Livingston	49.5
"	*	McCracken	66.7
"	*	McLean	0.0
Illinois	*	Massac	100.0
Indiana	*	Perry	100.0
"		Pike	2.3
Illinois	*	Pope	100.0
Indiana	*	Posey	25.4

TABLE 1e (cont'd)

OHIO RIVER MAIN STEM-EVANSVILLE

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Illinois	*	Pulaski	100.0
"	*	Saline	0.0
Indiana	*	Spencer	98.0
Illinois		Union	44.2
Kentucky	*	Union	59.6
Indiana	*	Vanderburgh	71.9
"	*	Warwick	96.6
Kentucky	*	Webster	10.5
Tributaries			
Saline River			
Illinois		Franklin	9.6
"	*	Gallatin	80.2
"		Hamilton	51.1
"	*	Hardin	20.3
"	*	Johnson	13.9
"	*	Saline	100.0
"		White	11.9
"		Williamson	28.1

TABLE le (cont'd)

OHIO RIVER MAIN STEM-EVANSVILLE

Direct Drainage and Minor Tributaries
Counties in Basin

State		County	Percent of Land Area in Basin
Tradewater River			
Kentucky	*	Caldwell	55.3
"		Christian	13.8
"	*	Crittenden	23.0
"		Hopkins	47.1
"	*	Union	40.4
"	*	Webster	49.3

*Counties considered in economic projections of Ohio River Main Stem-Evansville.

TABLE 2

OHIO RIVER MAIN STEM

Minor Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from Pittsburgh
Upper Ohio			
Chartiers Creek,Pa.	277		2.5
Raccoon Creek, Pa.	200		29.6
L.Beaver River, Ohio	510	51	39.5
Yellow Creek, Ohio	240	34	50.4
Cross Creek, Ohio	128	27	71.6
Buffalo Creek, W.Va.	160		74.7
Short Creek, Ohio	147	29	81.4
Wheeling Creek, Ohio	108	30	91.0
Wheeling Creek, W.Va.	300		91.0
McMahon Creek, Ohio	91	28	94.7
Grave Creek, W.Va.	75		102.5
Captina Creek, Ohio	181	39	109.6
Fish Creek, West Va.	250		113.8
Sunfish Creek, Ohio	114	31	118.0
Fishing Creek, W.Va.	220		128.3
Middle Island Crk.,W.Va.	560		154.0
L.Muskingum River, Ohio	315	70	168.3
Duck Creek, Ohio	288	52	170.7
L.Hocking River, Ohio	103	18	191.8
Hocking River, Ohio	1,200	95	199.5
Federal Creek	145	24	
Sunday Creek	139	27	
Monday Creek	116	27	
Clear Creek	91	23	
Rush Creek	236	37	
Ohio-Huntington Reach			
Shade River, Ohio	221	38	210.6
Sandy Creek, W.Va.	115		220.6
Mill Creek, W.Va.	230		231.5
Leading Creek, Ohio	151	30	254.2
Raccoon Creek, Ohio	684	109	276.0
Symmes Creek, Ohio	356	70	309.0
Twelvepole Creek, W.Va.	440		313.3
Pine Creek, Ohio	185	48	346.9
L.Scioto River, Ohio	233	41	349.0
Tygarts Creek, Kentucky	336		353.3
Kinniconnick Creek, Ky.	253		368.1

TABLE 2 (cont'd)

OHIO RIVER MAIN STEM

Minor Tributaries and Drainage Areas

Tributary	Drainage Area Sq. Miles	Length of Stream (miles)	Miles from Pittsburgh
Ohio-Cincinnati Reach			
Ohio Brush Creek, Ohio	435	57	388.0
Eagle Creek, Ohio	154	31	415.7
Whiteoak Creek, Ohio	234	49	423.9
Mill Creek, Ohio	166	28	472.5
Tanners Creek, Indiana	136		494.8
Laughery Creek, Indiana	350		498.7
Ohio-Louisville Reach			
L.Kentucky River, Ky.	147	35	546.5
Indian Kentucky R., Ind.	150		550.5
Silver Creek, Ind.	225		606.5
Big Indian Creek, Ind.	249		657.0
Blue River, Ind.	466		663.0
Sinking Creek, Ky.	199		700.9
Ohio-Evansville Reach			
Anderson Creek, Ind.	276		731.3
Blackford Creek, Ky.	124		742.2
L.Pigeon Creek, Ind.	415		773.0
Pigeon Creek, Ind.	375		792.9
Saline River, Ill.	1,235		867.5
Tradewater River, Ky.	995		873.5
Cache River, Ill.	720		975.7

TABLE 3a

OHIO RIVER MAIN STEM-UPPER

Population of Principal Communities
Direct Drainage and Minor Tributaries

City	County	State	1910	1920	1930	1940	1950	1960
Pittsburgh 1/	Allegheny	Pennsyl.	533,905	588,343	669,817	671,659	676,806	604,332
Wheeling	Ohio	West Va.	41,641	56,208	61,659	61,099	58,891	53,400
Parkersburg	Wood	" "	17,842	20,050	29,623	30,103	29,684	44,797
Steubenville	Jefferson	Ohio	22,391	28,508	35,422	37,651	35,872	32,495
Lancaster	Fairfield	"	13,093	14,706	18,716	21,940	24,180	29,916
Weirton	Hancock Brooke	West Va.	-	-	-	-	24,005	28,201
Aliquippa 1/	Beaver	Pennsyl.	1,743	2,931	27,116	27,023	26,132	26,369
Washington	Washington	"	18,788	21,480	24,545	26,166	26,280	23,545
East Liverpool	Columbiana	Ohio	20,387	21,411	23,329	23,555	24,217	22,306
Marietta	Washington	"	12,923	15,140	14,285	14,543	16,006	16,847
Athens	Athens	"	5,463	6,418	7,252	7,696	11,660	16,470
Moundsville	Marshall	West Va.	8,918	10,669	14,411	14,168	14,772	15,163
Ambridge 1/	Beaver	Pennsyl.	5,205	12,730	20,227	18,968	16,429	13,865
Salem	Columbiana	Ohio	8,943	10,305	10,622	12,301	12,754	13,854
McKees Rocks 1/	Allegheny	Pennsyl.	14,702	16,713	18,116	17,021	16,241	13,185
Martins Ferry	Belmont	Ohio	9,133	11,634	14,524	14,729	13,220	11,919
Carnegie 1/	Allegheny	Pennsyl.	10,009	11,516	12,497	12,663	12,105	11,887
Canonsburg	Washington	"	3,891	10,632	12,558	12,599	12,072	11,877
Castle Shannon 1/	Allegheny	"	-	2,353	3,810	3,970	5,459	11,836
Bellaire	Belmont	Ohio	12,946	15,061	13,327	13,799	12,573	11,502
Bellevue 1/	Allegheny	Pennsyl.	6,323	8,198	10,252	10,488	11,604	11,412
Coraopolis 1/	"	"	5,252	6,162	10,724	11,086	10,498	9,643

1/ Part of Pittsburgh, Pennsylvania urbanized area.

TABLE 3b

OHIO RIVER MAIN STEM-HUNTINGTON

Populations of Principal Communities
Direct Drainage and Minor Tributaries

City	County	State	1910	1920	1930	1940	1950	1960
Huntington	Cabell Wayne	West Va.	31,161	50,177	75,572	78,836	86,353	83,627
Portsmouth	Scioto	Ohio	23,481	33,011	42,560	40,466	36,798	33,637
Ashland	Boyd	Kentucky	8,688	14,729	29,074	29,537	31,131	31,283
Ironton	Lawrence	Ohio	13,147	14,007	16,621	15,851	16,333	15,745
Gallipolis	Gallia	"	7,199	6,642	7,809	7,832	7,871	8,775
Point Pleasant	Mason	West Va.	2,045	3,059	3,301	3,538	4,596	5,785
Wellston	Jackson	Ohio	6,875	6,687	5,319	5,537	5,691	5,728
Kenova	Wayne	West Va.	992	2,162	3,680	3,902	4,230	4,577
New Boston	Scioto	Ohio	1,858	4,817	5,931	6,024	4,754	3,984

TABLE 3c

OHIO RIVER MAIN STEM-CINCINNATI

Populations of Principal Communities
Direct Drainage and Minor Tributaries

City	County	State	1910	1920	1930	1940	1950	1960
Cincinnati	Hamilton	Ohio	363,591	401,247	451,160	455,610	503,998	502,550
Covington 1/	Kenton	Kentucky	53,270	57,121	65,252	62,018	64,452	60,376
Norwood 1/	Hamilton	Ohio	16,185	29,966	33,411	34,010	35,001	34,580
Newport 1/	Campbell	Kentucky	30,309	29,317	29,744	30,631	31,044	30,070
Ft. Thomas 1/	"	"	-	5,028	10,008	11,034	10,870	14,896
Reading 1/	Hamilton	Ohio	3,985	4,540	5,723	6,079	7,836	12,832
North College Hill 1/	"	"	-	1,104	4,139	5,231	7,921	12,035
Cheviot 1/	"	"	1,930	4,108	8,046	9,043	9,944	10,701
Bellevue 1/	Campbell	Kentucky	6,683	7,379	8,497	8,741	9,040	9,336
Dayton 1/	"	"	6,979	7,646	9,071	8,379	8,977	9,050
Maysville	Mason	"	6,141	6,107	6,557	6,572	8,632	8,484
Deer Park 1/	Hamilton	Ohio	-	824	2,642	3,510	7,241	8,423
Lincoln Heights 1/	"	"	-	-	-	-	5,531	7,798
Wyoming 1/	"	"	1,893	2,323	3,767	4,466	5,582	7,736
Erlanger 1/	Kenton	Kentucky	700	711	1,853	2,416	3,694	7,072
St. Bernard 1/	Hamilton	Ohio	5,002	6,312	7,487	7,387	7,066	6,778
Silverton 1/	"	"	459	795	1,843	2,907	4,827	6,682
Mt. Healthy 1/	"	"	1,799	2,255	3,530	3,997	5,533	6,553
Ludlow 1/	Kenton	Kentucky	4,163	4,582	6,485	6,185	6,374	6,233
Florence 1/	Boone	"	250	268	450	776	1,325	5,837
Greenhills 1/	Hamilton	Ohio	-	-	-	2,677	3,005	5,407
Lockland 1/	"	"	3,439	4,007	5,703	5,601	5,736	5,292
Lawrenceburg	Dearborn	Indiana	3,930	3,466	4,072	4,413	4,806	5,004

1/ Part of Cincinnati, Ohio urbanized area.

TABLE 3d

OHIO RIVER MAIN STEM-LOUISVILLE

Populations of Principal Communities
Direct Drainage and Minor Tributaries

City	County	State	1910	1920	1930	1940	1950	1960
Louisville	Jefferson	Kentucky	223,928	234,891	307,745	319,077	369,129	390,639
New Albany 2/	Floyd	Indiana	20,629	22,992	25,819	25,414	29,346	37,812
Jeffersonville 2/	Clark	"	10,412	10,098	11,946	11,493	14,685	19,522
Shively 2/	Jefferson	Kentucky	-	-	-	1,273	2,401	15,155
Pleasure Ridge Park 1/ 2/	"	"	-	-	-	-	-	10,612
Valley Station 1/ 2/	"	"	-	-	-	-	-	10,553
Madison	"	Indiana	6,934	6,711	6,530	6,923	7,506	10,488
St. Mathews 2/	"	Kentucky	-	-	-	-	-	8,738
Clarksville 2/	Clark	Indiana	2,743	2,322	2,243	2,386	5,905	8,088
Charlestown	"	"	864	820	859	939	4,785	5,726
Salem	Washington	"	2,283	2,836	3,194	3,194	3,271	4,546
Jeffersontown	Jefferson	Kentucky	345	350	614	899	1,246	3,431
Carrollton	Carroll	"	1,906	2,281	2,409	2,910	3,226	3,218
Corydon	Harrison	Indiana	1,703	1,785	2,009	1,865	1,944	2,701
Sellersburg	Clark	"	676	915	1,050	1,121	1,664	2,679

1/ Unincorporated
2/ Part of Louisville, Kentucky urbanized area.

TABLE 3e

OHIO RIVER MAIN STEM-EVANSVILLE

Populations of Principal Communities
Direct Drainage and Minor Tributaries

City	County	State	1910	1920	1930	1940	1950	1960
Evansville	Vanderburgh	Indiana	69,647	85,264	102,249	97,062	128,636	141,543
Owensboro	Daviess	Kentucky	16,011	17,424	22,765	30,245	33,651	42,471
Paducah	McCracken	"	22,760	24,735	33,541	33,765	32,828	34,479
Henderson	Henderson	"	11,452	12,169	11,668	13,160	16,837	16,892
Cairo	Alexander	Illinois	14,548	15,203	13,532	14,407	12,123	9,348
Harrisburg	Saline	"	5,309	7,125	11,625	11,453	10,999	9,171
Metropolis	Massac	"	4,655	5,055	5,573	6,287	6,093	7,339
Tell City	Perry	Indiana	3,369	4,086	4,873	5,395	5,735	6,609
Boonville	Warrick	"	3,934	4,451	4,208	4,526	5,092	4,801
Providence	Webster	Kentucky	2,084	4,151	4,742	4,397	3,905	3,771
Morganfield	Union	"	2,725	2,651	2,551	3,079	3,257	3,741
Eldorado	Saline	Illinois	3,366	5,004	4,482	4,891	4,500	3,573
Dawson Springs	Hopkins	Kentucky	1,350	1,762	2,311	2,560	2,374	3,002
McLeansboro	Hamilton	Illinois	1,796	1,927	2,162	2,528	3,008	2,951
Earlington	Hopkins	Kentucky	3,931	3,652	3,309	2,858	2,753	2,786

TABLE 4

OHIO RIVER MAIN STEM

Reservoirs - Area 100 Acres or Greater

Name	Purpose	Perm.Pool Area (acres)	Storage (acre-feet) Flood Control	Water Supply	Other
Upper Ohio					
Tom Jenkins	F, W, R	394	17,600	5,800	3,500
Belmont Lake	R	117			
Guilford Lake	R	326			2,510
Salem	W	115		2,086	
Dow Lake	R	153			1,884
Forked Run Lake	R	107			
Hocking County Lake	R	340			
Ohio River-Huntington					
East Lynn1/	F, A	823	70,795		11,705
Lake Hope	R	120			1,506
Jackson Lake	R	243			1,700
Tycoon Lake	R	204			2,000
Ohio River-Cincinnati					
West Fork-Mill Creek	F, R	183	9,850		1,530
Grant Lake	R	221			1,190
Batesville	W	200		2,100	
Versailles	W, R	266		2,970	
Ohio River-Louisville					
Georgetown	W	455			
Doe Run	R	200			
Ohio River-Evansville					
Lake Brashear	W, R	857		9,000	
Lake Egypt		2,400			42,550
Open Pond		544			
Harrisburg New North Reservoir	W	202		2,763	
Sarah Coal Co. Lake		102			614
Horseshoe Lake	R	2,400			
Mermet Lake	R	690			
The Big Sink		135			

1/ Under Construction

F - Flood Control
R - Recreation
W - Water Supply
A - Low flow regulation

TABLE 5a

OHIO RIVER MAIN STEM AND MINOR TRIBUTARIES

Flow Data[1]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	30 Consecutive Day Avg. Disc. 10 Yr. Freq. (cfs)[2] Nat.	30 Consecutive Day Avg. Disc. 10 Yr. Freq. (cfs)[2] Modified
Main Stem						
Ohio River						
Sewickley, Pennsylvania	19,500	32,740	1,800	574,000	2,370	5,580
Bellaire, Ohio	25,100	40,850		412,000		
St. Marys, W. Va.	26,850			421,000		
Parkersburg, W. Va.	35,600	50,730	2,290	440,000	3,590	7,520
Pomeroy, Ohio	40,500			554,000		
Point Pleasant, W. Va.	52,760			522,000		
Huntington, W. Va.	55,900	77,620	3,200	654,000	4,800	9,640
Ashland, Kentucky	60,750		3,760	589,000		
Maysville, Kentucky	70,130	91,550		635,000	5,795	10,750
Cincinnati, Ohio	76,580	96,810		894,000	6,250	11,450
Louisville, Kentucky	91,170	113,700	2,100	1,100,000	7,415	12,450
Evansville, Indiana	107,000	133,900		1,410,000	8,705	16,200
Golconda, Illinois	143,900			1,010,000		
Metropolis, Illinois	203,000	258,500	20,600	1,780,000	20,233	47,900

[1] Excerpted from "Hydrology of the Ohio River Basin," Appendix C, Ohio River Basin Comprehensive Survey.

[2] Corps of Engineers "Group A Reservoirs" (1963) listed in.[1]

TABLE 5b

OHIO RIVER MAIN STEM AND MINOR TRIBUTARIES

Flow Data[1/]

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Tributaries						
Little Beaver River						
E. Liverpool, Ohio	505	522	12	25,000		
Middle Island Creek						
Little, W. Va.	458	617	0	25,000		
Hocking River Basin						
Enterprise, Ohio	460	435	12	25,200		
Athens, Ohio	944	978	9	30,400	37	
Raccoon Creek						
Adamsville, Ohio	587	655	1.4	15,500		
Twelvepole Creek						
Wayne, W. Va.	291	326	0	14,000		
Tygarts Creek						
Near Greenup, Kentucky	242	304	0	14,800		
Ohio Brush Creek						
West Union, Ohio	388	442	0	51,600		
Mill Creek						
Carthage, Ohio	116		0	8,900		

TABLE 5b (cont'd)

OHIO RIVER MAIN STEM AND MINOR TRIBUTARIES

Flow Data

Location	Drainage Area Above (sq.mi.)	Avg. Disc. (cfs)	Instantaneous Min. Disc. (cfs)	Instantaneous Max. Disc. (cfs)	7 Day Avg. 1 in 10 Yr. Low Flow (cfs)	1 Day in 30 Yrs. Low Flow (cfs)
Blue River Basin						
Whitecloud, Indiana	461	617	9.2	28,500	12	
Saline River						
Junction, Illinois	1,040	1,211	0.9	37,400		
Tradewater River						
Olney, Kentucky	255	328	0	7,960		

1/ Excerpted from "Hydrology of the Ohio River Basin," Appendix C, Ohio River Basin Comprehensive Survey.

TABLE 6a-1

OHIO RIVER MAIN STEM-PITTSBURGH SMSA

Economic Subarea C
Base and Projected Populations

State	County	1960		1980		2000		2020	
		Total	Urban	Total	Urban	Total	Urban	Total	Urban
Pennsyl.	Allegheny	1,628,600	1,571,100						
"	Beaver	206,900	146,800						
"	Washington	217,300	89,400						
"	Westmoreland	352,600	213,900						
Total Subarea C		2,405,400	2,021,200	2,654,440	2,196,000	3,088,810	2,540,000	3,300,000	3,010,000

TABLE 7a-1

OHIO RIVER MAIN STEM-PITTSBURGH SMSA

Economic Subarea C
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Pennsyl.	Allegheny	577,600	194,500										
"	Beaver	70,700	38,000										
"	Washington	70,800	25,900										
"	Westmoreland	113,000	49,800										
Total Subarea C		832,100	308,200	7676.9	114	88	148	135	84	220	165	84	339

*In millions of 1960 dollars.
**1960 = 100

TABLE 6a-2

OHIO RIVER MAIN STEM-UPPER

Economic Subarea E
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation E-1									
Ohio	Athens	47,000	21,300						
West Va.	Doddridge	7,000	0						
Ohio	Monroe	15,300	3,000						
West Va.	Pleasants	7,100	0						
"	Tyler	10,000	900						
Ohio	Washington	51,700	22,300						
West Va.	Wetzel	19,300	7,800						
"	Wood	78,300	56,800						
	Subtotal	235,700	112,100	259,300		318,780		380,000	
Area Designation E-2									
Ohio	Belmont	83,900	41,800						
West Va.	Brooke	28,900	15,700						
Ohio	Columbiana	107,000	58,800						
West Va.	Hancock	39,600	27,900						
Ohio	Jefferson	99,200	55,100						
West Va.	Marshall	38,000	21,000						
"	Ohio	68,400	59,600						
	Subtotal	465,000	279,900	485,600		536,780		610,000	
Total Subarea E		700,700	392,000	744,900	439,000	855,560	540,000	990,000	695,000

TABLE 7a-2

OHIO RIVER MAIN STEM-UPPER

Economic Subarea E
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation E-1													
Ohio	Athens	14,300	2,270										
West Va.	Doddridge	1,900	320										
Ohio	Monroe	4,300	1,190										
West Va.	Pleasants	2,200	670										
" "	Tyler	2,800	1,030										
Ohio	Washington	16,600	4,690										
West Va.	Wetzel	5,400	2,080										
" "	Wood	27,100	10,260										
	Subtotal	74,600	22,510	582.3	125	108	177	160	121	288	204	133	431
Area Designation E-2													
Ohio	Belmont	26,500	7,640										
West Va.	Brooke	9,900	4,930										
Ohio	Columbiana	37,400	16,950										
West Va.	Hancock	13,900	8,490										
Ohio	Jefferson	32,800	13,260										
West Va.	Marshall	11,500	4,520										
" "	Ohio	25,000	6,430										
	Subtotal	157,000	62,220	1505.0	106	77	131	123	69	187	152	67	261
Total Subarea E		231,600	84,730	2087.3	112	85	144	135	83	214	168	84	308

*In millions of 1960 dollars.
**1960 = 100

TABLE 8a

OHIO RIVER MAIN STEM-UPPER

Direct Drainage and Minor Tributaries
Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subareas	
Pennsylvania	Allegheny	C	Pittsburgh SMSA
"	Beaver	C	Pittsburgh SMSA
"	Butler	D	Beaver
Ohio	Carroll	F-3	Muskingum
"	Fairfield	I-1	Scioto
Pennsylvania	Greene	B-1	Monongahela
Ohio	Harrison	F-3	Muskingum
"	Hocking	I-1	Scioto
Pennsylvania	Lawrence	D	Beaver
Ohio	Mahoning	D	Beaver
"	Morgan	F-1	Muskingum
"	Noble	F-1	Muskingum
"	Perry	F-1	Muskingum
Pennsylvania	Washington	C	Pittsburgh SMSA

TABLE 6b

OHIO RIVER MAIN STEM-HUNTINGTON

Economic Subarea H
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation H-1									
Kentucky	Greenup	29,200	8,300						
"	Lewis	13,100	0						
Ohio	Pike	19,400	3,800						
"	Scioto	84,200	43,400						
	Subtotal	145,900	55,500	171,900		206,400		250,000	
Area Designation H-2									
Kentucky	Boyd	52,200	39,800						
West Va.	Cabell	108,200	79,800						
Ohio	Lawrence	55,400	24,900						
West Va.	Wayne	39,000	12,900						
	Subtotal	254,800	157,400	282,000		314,800		360,000	
Area Designation H-3									
Ohio	Gallia	26,100	8,800						
"	Jackson	29,400	12,700						
West Va.	Jackson	18,500	6,200						
"	Mason	24,500	5,800						
Ohio	Meigs	22,200	6,700						
"	Vinton	10,300	0						
	Subtotal	131,000	40,200	145,800		165,500		185,000	
Total Subarea H		531,700	253,000	599,700	320,000	686,700	400,000	795,000	510,000

TABLE 7b

OHIO RIVER MAIN STEM-HUNTINGTON

Economic Subarea H
Base and Projected Industrial Activity

State	County	1960 Total Empl.	1960 Mfg. Empl.	1960 Mfg.* Output	1980 Index** Total Empl.	1980 Index** Mfg. Empl.	1980 Index** Mfg. Output	2000 Index** Total Empl.	2000 Index** Mfg. Empl.	2000 Index** Mfg. Output	2020 Index** Total Empl.	2020 Index** Mfg. Empl.	2020 Index** Mfg. Output
Area Designation H-1													
Kentucky	Greenup	7,700	2,150										
"	Lewis	3,500	870										
Ohio	Pike	4,900	1,490										
"	Scioto	24,800	8,940										
	Subtotal	40,900	13,450	363.0	123	109	176	153	124	310	199	134	544
Area Designation H-2													
Kentucky	Boyd	16,600	5,790										
West Va.	Cabell	37,300	9,220										
Ohio	Lawrence	16,400	6,250										
West Va.	Wayne	10,000	2,740										
	Subtotal	80,300	24,000	599.0	121	94	184	151	100	346	198	107	649
Area Designation H-3													
Ohio	Gallia	7,100	700										
"	Jackson	8,400	2,530										
West Va.	Jackson	5,100	1,780										
"	Mason	6,800	1,810										
Ohio	Meigs	6,100	920										
"	Vinton	2,500	700										
	Subtotal	36,000	8,440	213.7	132	119	199	169	136	443	243	152	955
Total Subarea H		157,200	45,890	1175.7	124	103	184	156	114	352	209	123	672

*In millions of 1960 dollars.
**1960 = 100

TABLE 8b

OHIO RIVER MAIN STEM-HUNTINGTON

Direct Drainage and Minor Tributaries
Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea
Ohio	Athens	E-1 Upper Ohio
Kentucky	Carter	J-1 Guyandot-Big Sandy-Little Sandy
Ohio	Hocking	I-1 Scioto
West Virginia	Lincoln	J-3 Guyandot-Big Sandy-Little Sandy
" "	Mingo	J-3 Guyandot-Big Sandy-Little Sandy
" "	Putnam	G-1 Kanawha-Little Kanawha
" "	Roane	G-4 Kanawha-Little Kanawha
" "	Wirt	G-3 Kanawha-Little Kanawha

TABLE 6c

OHIO RIVER MAIN STEM-CINCINNATI

Economic Subarea K
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation K-1									
Indiana	Dearborn	28,700	12,000						
Kentucky	Gallatin	3,900	0						
Indiana	Ohio	4,200	0						
"	Ripley	20,600	3,300						
"	Switzerland	7,100	0						
	Subtotal	64,500	15,300	90,600		134,000		205,000	
Area Designation K-2									
Kentucky	Boone	21,900	5,800						
"	Campbell	86,800	72,000						
Ohio	Clermont	80,500	11,500						
"	Hamilton	864,100	817,100						
Kentucky	Kenton	120,700	101,700						
	Subtotal	1,174,000	1,008,100	1,393,700		1,629,600		1,870,000	
Area Designation K-3									
Ohio	Adams	20,000	0						
Kentucky	Bracken	7,400	0						
Ohio	Brown	25,200	2,700						
Kentucky	Mason	18,400	8,500						
	Subtotal	71,000	11,200	81,600		122,000		165,000	
Total Subarea K		1,309,500	1,034,600	1,565,900	1,304,000	1,885,600	1,590,000	2,240,000	1,910,000

TABLE 7c

OHIO RIVER MAIN STEM-CINCINNATI

Economic Subarea K
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation K-1													
Indiana	Dearborn	9,800	4,170										
Kentucky	Gallatin	1,400	200										
Indiana	Ohio	1,500	480										
"	Ripley	7,000	2,290										
"	Switzerland	2,800	640										
	Subtotal	22,500	7,780	214.1	145	124	206	222	150	439	340	232	940
Area Designation K-2													
Kentucky	Boone	7,400	1,790										
"	Campbell	31,000	10,040										
Ohio	Clermont	26,600	10,700										
"	Hamilton	323,500	109,150										
Kentucky	Kenton	43,800	12,230										
	Subtotal	432,300	143,910	3393.2	120	107	200	141	108	352	168	106	611
Area Designation K-3													
Ohio	Adams	5,900	990										
Kentucky	Bracken	2,600	360										
Ohio	Brown	8,200	2,060										
Kentucky	Mason	6,600	1,630										
	Subtotal	23,300	5,040	111.6	124	128	231	197	154	489	288	264	1030
Total Subarea K		478,100	156,730	3718.9	121	108	201	147	112	360	182	117	641

*In millions of 1960 dollars.
**1960 = 100

TABLE 8c

OHIO RIVER MAIN STEM-CINCINNATI

Direct Drainage and Minor Tributaries
Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Ohio	Butler	L-2	Little Miami-Miami
Indiana	Decatur	Q-2	White
"	Franklin	L-1	Little Miami-Miami
Ohio	Highland	I-1	Scioto
Kentucky	Pendleton	M-3	Licking-Kentucky-Salt
Ohio	Ross	I-1	Scioto

TABLE 6d

OHIO RIVER MAIN STEM-LOUISVILLE

Economic Subarea N
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation N-1									
Kentucky	Breckinridge	14,700	0						
Indiana	Crawford	8,400	0						
"	Harrison	19,200	2,700						
Kentucky	Meade	18,900	0						
	Subtotal	61,200	2,700	115,600		188,020		280,000	
Area Designation N-2									
Kentucky	Bullitt	15,700	0						
Indiana	Clark	62,800	43,000						
"	Floyd	51,400	37,800						
Kentucky	Jefferson	610,900	540,500						
"	Oldham	13,400	0						
	Subtotal	754,200	621,300	957,300		1,187,600		1,400,000	
Area Designation N-3									
Kentucky	Carroll	8,000	3,200						
Indiana	Jefferson	24,100	10,100						
Kentucky	Trimble	5,100	0						
	Subtotal	37,200	13,300	68,670		98,000		140,000	
Total Subarea N		852,600	637,300	1,141,570	928,000	1,473,620	1,240,000	1,820,000	1,531,000

TABLE 7d

OHIO RIVER MAIN STEM-LOUISVILLE

Economic Subarea N
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation N-1													
Kentucky	Breckinridge	4,400	530										
Indiana	Crawford	2,600	710										
"	Harrison	6,200	1,770										
Kentucky	Meade	3,300	570										
	Subtotal	16,500	3,580	84.8	249	186	319	384	255	696	605	344	1558
Area Designation N-2													
Kentucky	Bullitt	4,700	1,710										
Indiana	Clark	21,500	7,080										
"	Floyd	17,900	6,000										
Kentucky	Jefferson	216,100	66,990										
"	Oldham	4,000	640										
	Subtotal	264,200	82,420	2061.4	129	142	230	167	179	456	217	217	869
Area Designation N-3													
Kentucky	Carroll	2,500	380										
Indiana	Jefferson	8,000	1,600										
Kentucky	Trumble	1,800	230										
	Subtotal	12,300	2,210	55.6	198	185	270	299	279	647	435	411	1600
Total Subarea N		293,000	88,210	2201.8	139	144	234	185	185	470	248	228	914

*In millions of 1960 dollars.
**1960 = 100

TABLE 8d

OHIO RIVER MAIN STEM-LOUISVILLE

Direct Drainage and Minor Tributaries
Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Kentucky	Hardin	P-2	Green
"	Henry	M-2	Licking-Kentucky-Salt
Indiana	Orange	Q-2	White
"	Scott	Q-2	White
"	Washington	Q-2	White

TABLE 6e

OHIO RIVER MAIN STEM-EVANSVILLE

Economic Subarea 0
Base and Projected Populations

State	County	1960 Total	1960 Urban	1980 Total	1980 Urban	2000 Total	2000 Urban	2020 Total	2020 Urban
Area Designation 0-1									
Kentucky	Ballard	8,300	0						
"	Caldwell	13,100	5,600						
"	Crittenden	8,600	0						
Illinois	Gallatin	7,600	0						
"	Hardin	5,900	0						
"	Johnson	6,900	0						
Kentucky	Livingston	7,000	0						
"	McCracken	57,300	34,500						
Illinois	Massac	14,300	7,300						
"	Pope	4,100	0						
Indiana	Posey	19,200	6,000						
Illinois	Pulaski	10,500	0						
"	Saline	26,200	12,700						
Kentucky	Union	14,500	3,700						
"	Webster	14,200	3,800						
	Subtotal	217,700	73,600	224,600		249,400		272,000	
Area Designation 0-2									
Kentucky	Henderson	33,500	16,900						
Indiana	Vanderburgh	165,800	143,700						
	Subtotal	199,300	160,600	241,400		284,700		363,000	
Area Designation 0-3									
Kentucky	Daviess	70,600	42,500						
"	Hancock	5,300	0						
"	McLean	9,400	0						
Indiana	Perry	17,200	6,600						
"	Spencer	16,100	0						
"	Warrick	23,600	4,800						
	Subtotal	142,200	53,900	245,100		332,900		400,000	
Total Subarea 0		559,200	288,100	701,100	426,000	867,000	581,000	1,035,000	785,000

TABLE 7e

OHIO RIVER MAIN STEM-EVANSVILLE

Economic Subarea O
Base and Projected Industrial Activity

		1960			1980 Index**			2000 Index**			2020 Index**		
State	County	Total Empl.	Mfg. Empl.	Mfg.* Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output	Total Empl.	Mfg. Empl.	Mfg. Output
Area Designation O-1													
Kentucky	Ballard	2,700	470										
"	Caldwell	4,400	820										
"	Crittenden	2,600	460										
Illinois	Gallatin	2,100	240										
"	Hardin	1,600	50										
"	Johnson	2,300	300										
Kentucky	Livingston	2,000	340										
"	McCracken	19,800	4,650										
Illinois	Massac	4,700	1,000										
"	Pope	1,100	60										
Indiana	Posey	6,500	1,550										
Illinois	Pulaski	2,800	430										
"	Saline	7,400	700										
Kentucky	Union	4,300	330										
"	Webster	4,000	640										
	Subtotal	68,300	12,040	290.0	116	119	222	136	127	448	164	126	890
Area Designation O-2													
Kentucky	Henderson	11,700	3,210										
Indiana	Vanderburgh	58,600	18,150										
	Subtotal	70,300	21,360	502.2	115	126	192	154	127	329	202	172	753
Area Designation O-3													
Kentucky	Daviess	24,300	7,550										
"	Hancock	1,700	410										
"	McLean	3,000	720										
Indiana	Perry	6,000	2,690										
"	Spencer	5,800	1,320										
"	Warrick	7,700	2,000										
	Subtotal	48,500	14,690	323.2	178	130	199	241	150	356	338	187	551
Total Subarea O		187,100	48,090	1115.4	132	126	202	170	142	368	223	165	730

*In millions of 1960 dollars.
**1960 = 100

TABLE 8e

OHIO RIVER MAIN STEM-EVANSVILLE

Direct Drainage and Minor Tributaries
Counties Considered in Economic Base of Adjoining Subareas

State	County	Included in Economic Subarea	
Illinois	Alexander	*	
Kentucky	Christian	S-1	Cumberland
Indiana	DuBois	Q-1	White
"	Gibson	Q-1	White
Illinois	Hamilton	R-1	Wabash
Kentucky	Hopkins	P-1	Green
Indiana	Pike	Q-1	White
Illinois	Union	*	
"	Williamson	*	

* - Not included in Projective Economic Study of Ohio River Basin.

TABLE 9a

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Direct Drainage Areas											
Area Designation C											
Pennsyl.	Allegheny	6	155,300	148,300	7,000	13.390	12.790	.600	86	Ohio River, Wells	150.0
"	Beaver	9	108,360	65,210	43,150	14.150	8.650	5.500	131	Ohio River, Service Run, Wells	70.0
"	Washington	5	8,300	700	7,60C	.521	.052	.469	63	Dutch Fk.,Middle Fk.,Harmon Crk.,Wells	5.8
"	Westmoreland	0									0
	Subtotal	20	271,960	214,210	57,750	28.061	21.492	6.569	103		225.8
Area Designation E-1											
Ohio	Athens	0									0
West Va.	Doddridge	0									0
Ohio	Monroe	2	4,000	1,000	3,000	.560	.400	.160	140	Reservoir, Wells	33.0
West Va.	Pleasants	2	2,855	455	2,400	.147	.032	.115	51	Dog River, Wells	34.0
"	Tyler	1	2,800		2,800	.475		.475	170	Ohio River	0
Ohio	Washington	3	24,245	24,245		2.560	2.560		106	Wells	.5
West Va.	Wetzel	6	10,625	9,500	1,125	.761	.700	.061	72	Fishing Crk., Wells	45.0
West Va.	Wood	3	70,500	70,500		5.265	5.265		75	Wells	1.2
	Subtotal	17	115,025	105,700	9,325	9.768	8.957	0.811	85		113.7
Area Designation E-2											
Ohio	Belmont	11	51,110	29,940	21,170	6.363	3.702	2.661	125	Ohio R.,Captina Crk.,Impoundments, Little McMahon Crk., Wells	18.8
West Va.	Brooke	6	15,200	14,200	1,000	1.401	1.331	.070	92	Buffalo Crk., Wells	16.5
Ohio	Columbiana	10	71,355	17,355	54,000	6.927	2.332	4.595	97	Ohio R.,Cold Run Crk.,Riley Run, Res.on Baileys Run, Wells	0.5
West Va.	Hancock	4	40,330	31,700	8,630	3.062	2.800	.262	76	Ohio River, Wells	38.5
Ohio	Jefferson	15	68,085	20,285	47,800	8.357	1.917	6.440	123	Ohio River, Wells	136.0
West Va.	Marshall	4	27,100	25,000	2,100	1.688	1.425	.263	62	Grave Crk, Impoundments, Wells	47.7
"	Ohio	2	65,600		65,600	8.113		8.113	124	Atkinson Br.,N.Fk.Short Ck.,Well, Ohio River	6.7
	Subtotal	52	338,780	138,480	200,300	35.911	13.507	22.404	106		264.7

TABLE 9a (cont'd)

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Other Areas in Basin											
Ohio	Harrison	3	5,470	470	5,000*	.319	.040	.279	58	Tanbark Crk, Impoundments, Wells	0
"	Noble	1	1,855		1,855	.200		.200	108	Dog Run, Impoundments	0
	Subtotal	4	7,325	470	6,855	.519	.040	.479	71		0
Tributaries											
Middle Island Creek											
West Va.	Doddridge	1	1,600		1,600	.065		.065	41	Middle Island Creek	0
"	Tyler	1	800		800	.085		.085	106	Middle Island Creek	0
	Subtotal	2	2,400		2,400	.150		.150	63		0
Chartiers Creek											
Pennsyl.	Allegheny	0									0
"	Washington	2	60,000		60,000	3.600		3.600	60	Chartiers Crk., L.Chartiers Crk.	29.6
	Subtotal	2	60,000		60,000	3.600		3.600	60		29.6
Raccoon Creek											
Pennsyl.	Allegheny	0									0
"	Beaver	0									0
"	Washington	1	10,000		10,000	1.000		1.000	100	Raccoon Creek	.8
	Subtotal	1	10,000		10,000	1.000		1.000	100		.8

TABLE 9a (cont'd)

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Hocking River											
Ohio	Athens	7	30,405	20,405	10,000	2.928	2.128	.800	96	Burr Oak Lake, Hocking R., Wells	.2
"	Fairfield	4	32,655	32,655		3.370	3.370		103	Wells	3.0
"	Hocking	2	7,250	7,250		.338	.338		47	Wells	.2
"	Morgan	0									0
"	Perry	4	8,315	765	7,550	.497	.020	.477	60	L.Rush Crk.,Boston Crk., Wells	.1
"	Washington	0									0
	Subtotal	17	78,625	61,077	17,550	7.133	5.856	1.277	91		3.5
	TOTAL	115	884,115	519,937	364,180	86.142	49.852	36.290	98		638.1

TABLE 10a

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Direct Drainage												
Area Designation C												
From Central Supplies	271,960	103	28.0	296,400	115	34.0	344,000	125	43.0	405,000	138	56.0
Industrial			225.8			266.0			343.0			479.0
Subtotal			253.8			300.0			386.0			535.0
Area Designation E-1												
From Central Supplies	115,025	85	9.8	135,400	96	13.0	176,000	105	18.5	232,000	115	26.7
Industrial			113.7			161.0			232.0			320.3
Subtotal			123.5			174.0			250.5			347.0
Area Designation E-2												
From Central Supplies	338,780	106	35.9	376,000	118	44.4	442,000	129	57.0	557,000	140	78.0
Industrial			264.7			275.6			326.0			434.0
Subtotal			300.6			320.0			383.0			512.0
Other Areas in Basin												
From Central Supplies	7,325	71	.5	11,100	88	1.0	15,000	98	1.5	20,000	108	2.2
Industrial			0			0.2			0.3			0.4
Subtotal			.5			1.2			1.8			2.6

TABLE 10a (cont'd)

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

Tributaries	1960 Pop. Served	1960 Per Capita Use (gpcd)	1960 Total Use (mgd)	1980 Pop. Served	1980 Per Capita Use (gpcd)	1980 Total Use (mgd)	2000 Pop. Served	2000 Per Capita Use (gpcd)	2000 Total Use (mgd)	2020 Pop. Served	2020 Per Capita Use (gpcd)	2020 Total Use (mgd)
Middle Island Creek												
From Central Supplies	2,400	63	.2	2,800	83	0.2	3,600	94	0.3	4,800	102	0.5
Industrial			0			0.1			0.2			0.3
Subtotal			.2			0.3			0.5			0.8
Chartiers Creek												
From Central Supplies	60,000	60	3.6	65,400	80	5.2	75,400	93	7.0	89,000	102	9.1
Industrial			29.6			35.0			45.0			62.9
Subtotal			33.2			40.2			52.0			72.0
Raccoon Creek												
From Central Supplies	10,000	100	1.0	10,900	110	1.2	13,000	122	1.6	15,000	132	2.0
Industrial			.8			1.0			1.2			1.7
Subtotal			1.8			2.2			2.8			3.7
Hocking River												
From Central Supplies	78,625	91	7.1	125,800	100	12.6	178,000	110	19.6	246,000	122	30.0
Industrial			3.5			7.0			12.4			21.5
Subtotal			10.6			19.6			32.0			51.5

TABLE 10a (cont'd)

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Ohio River Main Stem - Upper												
From Central Supplies												
Total	884,115	98	86.1	1,023,800	110	111.6	1,247,000	121	148.5	1,568,800	132	204.5
Industrial Total			638.1			745.9			960.1			1320.1
GRAND TOTAL			724.2			857.5			1108.6			1524.6

TABLE 9b

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Direct Drainage											
Area Designation H-1											
Kentucky	Greenup	3	8,675	8,675		.543	.543		63	Wells	1.5
"	Lewis	1	1,800	1,800		.095	.095		53	Wells	.1
Ohio	Pike	0									0
"	Scioto	2	50,805		50,805	5.456		5.456	107	Ohio River, Skull Creek	85.0
	Subtotal	6	61,280	10,475	50,805	6.094	.638	5.456	99		86.6
Area Designation H-2											
Kentucky	Boyd	1	45,000		45,000	3.570		3.570	79	Ohio River	76.0
West Va.	Cabell	1	118,090		118,090	12.500		12.500	106	Ohio River	15.0
Ohio	Lawrence	4	21,450	4,450	17,000	1.902	.402	1.500	89	Ohio River, Wells	145.0
West Va.	Wayne	1	3,500	3,500		.216	.216		62	Wells	2.0
	Subtotal	7	188,040	7,950	180,090	18.188	.618	17.570	97		238.0
Area Designation H-3											
Ohio	Gallia	1	10,000	10,000		.850	.850		85	Wells	0.1
"	Jackson	0									0
West Va.	Jackson	2	4,400	2,400	2,000	.385	.300	.085	88	Wells, Mill Creek	18.0
"	Mason	3	12,700	12,700		.930	.930		73	Wells	19.0
Ohio	Meigs	5	17,990	1,990	16,000	1.650	.150	1.500	92	Ohio River, Wells	0
"	Vinton	0									0
	Subtotal	11	45,090	27,090	18,000	3.815	2.230	1.585	85		37.1

TABLE 9b (cont'd)

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Tributaries											
Raccoon Creek											
Ohio	Athens	0									0
"	Gallia	2	980	380	600	.055	.025	.030	56	Indian Creek, Well	0
"	Hocking	0									0
"	Jackson	2	8,595	1,795	6,800	.620	.120	.500	72	Lake Alma, L.Raccoon Creek, Wells	.1
"	Meigs	0									0
"	Vinton	2	1,825	1,825		.183	.183		100	Wells	.1
	Subtotal	6	11,400	4,000	7,400	.858	.328	.530	75		.2
Twelve Pole Creek											
West Va.	Cabell	0									0
"	Lincoln	0									0
"	Mingo	0									0
"	Wayne	1	1,500		1,500	.107		.107	71	Twelve Pole Creek	0
	Subtotal	1	1,500	—	1,500	.107	—	.107	71		0
Tygarts Creek											
Kentucky	Carter	1	2,960		2,960	.450		.450	152	Lake on Perry Branch	0
"	Greenup	0									0
	Subtotal	1	2,960	—	2,960	.450	—	.450	152		0
	TOTAL	32	310,270	49,515	260,755	29.512	3.814	25.698	95		361.9

TABLE 10b

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Direct Drainage												
Area Designation H-1												
From Central Supplies	61,280	99	6.1	82,100	110	9.0	107,000	121	13.0	142,000	130	18.5
Industrial			86.6			125.0			202.0			345.0
Subtotal			92.7			134.0			215.0			363.5
Area Designation H-2												
From Central Supplies	188,040	97	18.2	236,900	107	25.3	284,000	118	33.5	357,000	130	46.4
Industrial			238.0			340.0			515.0			805.0
Subtotal			256.2			365.3			548.5			851.4
Area Designation H-3												
From Central Supplies	45,090	85	3.8	56,800	95	5.4	69,000	105	7.3	86,000	116	10.0
Industrial			37.1			59.0			107.0			205.0
Subtotal			40.9			64.4			114.3			215.0
Tributaries												
Raccoon Creek												
From Central Supplies	11,400	75	.9	14,400	90	1.3	18,000	99	1.8	22,000	105	2.3
Industrial			.2			0.3			0.6			1.1
Subtotal			1.1			1.6			2.4			3.4

TABLE 10b (cont'd)

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Tributaries (cont'd)												
Twelve Pole Creek												
From Central Supplies	1,500	71	.1	1,900	88	0.2	2,300	98	0.2	2,900	108	0.3
Industrial			0			0.1			0.2			0.3
Subtotal			.1			0.3			0.4			0.6
Tygarts Creek												
From Central Supplies	2,960	152	.4	3,100	160	0.5	3,100	168	0.5	3,000	172	0.5
Industrial			0			0.1			0.2			0.3
Subtotal			.4			0.6			0.7			0.8
Ohio River Main Stem - Huntington												
From Central Supplies Total	310,270	95	29.5	395,200	104	41.7	483,400	115	56.3	612,900	126	78.0
Industrial Total			361.9			524.5			825.0			1356.7
GRAND TOTAL			391.4			566.2			881.3			1434.7

TABLE 9c

OHIO RIVER MAIN STEM - CINCINNATI

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Direct Drainage											
Area Designation K-1											
Indiana	Dearborn	3	12,805	12,805		1.500	1.500		117	Wells	16.0
Kentucky	Gallatin	1	1,600	1,600		.090	.090		56	Well	.2
Indiana	Ohio	1	2,500	2,500		.142	.142		57	Well	0
"	Ripley	5	8,445	450	7,995	0.977	.065	.912	116	Laughery Crk., Bob's Crk., Wells	0.2
"	Switzerland	1	1,400	1,400		.240	.240		171	Wells	0
	Subtotal	11	26,750	18,755	7,995	2.949	2.037	.912	110		16.4
Area Designation K-2											
Kentucky	Boone	0									0
"	Campbell	2	57,250	1,250	56,000	4.775	.175	4.600	83	Ohio River, Wells	0.5
Ohio	Clermont	2	3,734	3,734		.210	.210		56	Wells	0
"	Hamilton	2	801,400	1,400	800,000	99.200	.200	99.000	124	Ohio River, Wells	2.0
Kentucky	Kenton	1	90,000		90,000	8.100		8.100	90	Ohio River	0.8
	Subtotal	7	952,384	6,384	946,000	112.285	.585	111.700	118		3.3
Area Designation K-3											
Ohio	Adams	5	8,395	2,290	6,105	.565	.220	.345	67	Brush Creek, Lake, Wells	0
Kentucky	Bracken	1	1,750	1,750		.400	.400		229	Wells	0
Ohio	Brown	6	8,250	3,500	4,750	.621	.281	.340	75	White Oak Crk., Sterling Run, Wells	.1
Kentucky	Mason	1	9,510		9,510	1.000		1.000	105	Ohio River	0.5
	Subtotal	13	27,905	7,540	20,365	2.586	.901	1.685	93		0.6

TABLE 9c (cont'd)

OHIO RIVER MAIN STEM - CINCINNATI

Direct Drainge and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Tributary											
Mill Creek											
Ohio	Butler	0									0
"	Hamilton	3	22,300	22,300		3.220	3.220		144	Wells	27.0
	Subtotal	3	22,300	22,300		3.220	3.220		144		27.0
	TOTAL	34	1,029,339	54,979	974,36[illegible]	121.040	6.743	114.297	118		47.3

TABLE 10c

OHIO RIVER MAIN STEM - CINCINNATI

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Direct Drainage												
Area Designation K-1												
From Central Supplies	26,750	110	2.9	40,000	122	4.9	59,000	134	7.9	92,000	145	13.3
Industrial			16.4			27.1			48.0			96.0
Subtotal			19.3			32.0			55.9			109.3
Area Designation K-2												
From Central Supplies	952,384	118	112.3	1,191,000	130	155.0	1,419,000	141	200.0	1,630,000	154	251.0
Industrial			3.3			5.0			7.5			12.0
Subtotal			115.6			160.0			207.5			263.0
Area Designation K-3												
From Central Supplies	27,905	93	2.6	33,800	102	3.5	51,000	112	5.7	70,000	124	8.7
Industrial			0.6			1.1			1.9			4.0
Subtotal			3.2			4.6			7.6			12.7

TABLE 10c (cont'd)

OHIO RIVER MAIN STEM - CINCINNATI

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

Tributary	1960 Pop. Served	1960 Per Capita Use (gpcd)	1960 Total Use (mgd)	1980 Pop. Served	1980 Per Capita Use (gpcd)	1980 Total Use (mgd)	2000 Pop. Served	2000 Per Capita Use (gpcd)	2000 Total Use (mgd)	2020 Pop. Served	2020 Per Capita Use (gpcd)	2020 Total Use (mgd)
Mill Creek												
From Central Supplies	22,300	144	3.2	27,900	160	4.5	33,000	165	5.5	38,000	170	6.5
Industrial			27.0			41.5			62.0			97.0
Subtotal			30.2			46.0			67.5			103.5
Ohio River Main Stem - Cincinnati												
From Central Supplies												
Total	1,029,339	118	121.0	1,292,700	130	167.9	1,562,000	140	219.1	1,830,000	153	279.5
Industrial Total			47.3			74.7			119.4			209.0
GRAND TOTAL			168.3			242.6			338.5			488.5

TABLE 9d

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Direct Drainage											
Area Designation N-1											
Kentucky	Breckinridge	3	4,195	2,750	1,445	.266	.196	.070	63	Wells, Hardin Creek	0
Indiana	Crawford	2	1,500	1,500		.075	.075		50	Well, Springs	0
"	Harrison	2	4,000		4,000	.390		.390	98	Big Indian Crk., Impounding Reservoir and Spring	0.1
Kentucky	Meade	3	2,325	2,325		.134	.134		58	Wells, Springs	1.0
	Subtotal	10	12,020	6,575	5,445	.865	.405	.460	72		1.1
Area Designation N-2											
Kentucky	Bullitt	0									0
Indiana	Clark	3	34,535	34,535		3.840	3.840		111	Wells	3.1
"	Floyd	2	32,870		32,870	3.232		3.232	98	Ohio River, Impounding Reservoir	0
Kentucky	Jefferson	2	595,900	45,900	550,000	86.800	3.000	83.800	146	Ohio River, Wells	30.0
"	Oldham	2	5,200		5,200	.738		.738	142	Lake and Reservoir	0
	Subtotal	9	668,505	80,435	588,070	94.610	6.840	87.770	142		33.2
Area Designation N-3											
Kentucky	Carroll	0									2.0
Indiana	Jefferson	2	11,810	11,810		3.210	3.210		272	Wells	0
Kentucky	Trimble	2	2,100	2,100		.176	.176		84	Wells	0
	Subtotal	4	13,910	13,910		3.386	3.386		244		2.0

TABLE 9d (cont'd)

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served			Average Municipal Water Use (mgd)			Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
			Total	From Ground	From Surface	Total	From Ground	From Surface			
Other Areas in Basin											
Kentucky	Hardin	3	8,400	2,500	5,900	.790	.200	.590	94	Otter Crk.,Spring,Reservoir, Wells	0
"	Henry	1	600		600	.040		.040	67	Little Kentucky River Impoundment	0
	Subtotal	4	9,000	2,500	6,500	.830	.200	.630	92		0
Tributaries											
Blue River											
Indiana	Clark	0									0
"	Crawford	2	1,875	1,875		.142	.142		76	Wells and Springs	0
"	Floyd	0									0
"	Harrison	0									0
"	Orange	0									0
"	Washington	1	5,500		5,500	.600		.600	109	L.Salinda,Hoggatt Branch & Spring	.2
	Subtotal	3	7,375	1,875	5,500	.742	.142	.600			.2
	TOTAL	30	710,810	105,295	605,515	100.433	10.973	89.460	141		36.5

TABLE 10d

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Direct Drainage												
Area Designation N-1												
From Central Supplies	12,020	72	.9	24,800	88	2.2	42,000	98	4.1	62,000	108	6.7
Industrial			1.1			2.8			5.2			10.4
Subtotal			2.0			5.0			9.3			17.1
Area Designation N-2												
From Central Supplies	668,505	142	94.6	924,000	156	146.0	1,189,000	164	195.0	1,391,000	170	236.5
Industrial			33.2			62.0			105.0			180.0
Subtotal			127.8			208.0			300.0			416.5
Area Designation N-3												
From Central Supplies	13,910	244	3.4	27,800	248	6.9	40,000	254	10.2	59,000	260	15.3
Industrial			2.0			4.5			8.2			20.0
Subtotal			5.4			11.4			18.4			35.3
Other Areas in Basin												
From Central Supplies	9,000	92	0.8	10,000	100	1.0	12,800	110	1.4	26,000	122	3.2
Industrial			0			.1			.2			.4
Subtotal			0.8			1.1			1.6			3.6

TABLE 10d (cont'd)

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Tributary												
Blue River												
From Central Supplies	7,375	109	.7	13,700	124	1.7	22,000	132	2.9	33,000	142	4.7
Industrial			.2			.5			1.0			1.5
Subtotal			.9			2.2			3.9			6.2
Ohio River Main Stem - Louisville												
From Central Supplies Total	710,810	141	100.4	1,000,300	157	157.8	1,305,800	160	213.6	1,571,000	170	266.4
Industrial Total			36.5			69.9			119.6			212.3
GRAND TOTAL			136.9			227.7			333.2			478.7

TABLE 9e

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served Total	Population Served From Ground	Population Served From Surface	Average Municipal Water Use (mgd) Total	Average Municipal Water Use (mgd) From Ground	Average Municipal Water Use (mgd) From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Direct Drainage											
Area Designation O-1											
Kentucky	Ballard	3	2,488	2,488		.165	.165		66	Wells	0
"	Caldwell	0									0
"	Crittenden	1	4,200		4,200	.300		.300	71	Crooked Creek Impounding Reservoir	0
Illinois	Gallatin	0									0
"	Hardin	2	2,880	480	2,400	.284	.034	.250	99	Ohio River, Wells	0.1
"	Johnson	1	1,095		1,095	.130		.130	119	McCorkle and L.Cache Crk.Impoundments	0
Kentucky	Livingston	0									0
"	McCracken	1	52,000		52,000	4.500		4.500	87	Ohio River	.1
Illinois	Massac	3	9,465	9,465		1.155	1.155		122	Wells	2.5
"	Pope	1	800		800	.080		.080	100	Ohio River	0
Indiana	Posey	1	6,700		6,700	.680		.680	102	Ohio River	.6
Illinois	Pulaski	4	4,670	4,670		.240	.240		51	Wells	0.1
"	Saline	0									0
Kentucky	Union	2	6,335		6,335	.490		.490	77	Ohio River	0.1
"	Webster	0									0
	Subtotal	19	90,633	17,103	73,530	8.024	1.594	6.430	89		3.5
Area Designation O-2											
Kentucky	Henderson	2	23,850	580	23,270	3.040	.040	3.000	128	Ohio River and Wells	13.7
Indiana	Vanderburgh	2	150,125	125	150,000	22.303	.008	22.295	149	Ohio River, Wells	0
	Subtotal	4	173,975	705	173,270	25.343	.048	25.295	146		13.7

TABLE 9e (cont'd)

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Area Designation 0-3											
Kentucky	Daviess	1	53,800	53,800		5.540	5.540		103	Wells	7.0
"	Hancock	2	1,925	1,925		.145	.145		75	Wells	0
"	McLean	0									0
Indiana	Perry	3	10,900	10,900		.918	.918		84	Wells	.3
"	Spencer	3	3,975	2,495	1,480	.257	.171	.086	65	Lake, Wells	0
"	Warrick	2	9,800	9,800		.610	.610		62	Well	1.5
	Subtotal	11	80,400	78,920	1,480	7.470	7.384	.086	93		8.8
Other Areas in Basin											
Illinois	Alexander	1	9,200		9,200	1.500		1.500	163	Ohio River	0
Indiana	DuBois	1	600		600	.085		.085	142	Impounding Reservoir	.1
"	Gibson	1	5,000	5,000		.680	.680		136	Wells	.5
"	Pike	0									0
"	Union	0									0
	Subtotal	3	14,800	5,000	9,800	2.265	.680	1.585	153		.6

TABLE 9e (cont'd)

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Water Use

State	County	Number of Central Supplies	Population Served: Total	Population Served: From Ground	Population Served: From Surface	Average Municipal Water Use (mgd): Total	Average Municipal Water Use (mgd): From Ground	Average Municipal Water Use (mgd): From Surface	Per Capita (gpcd)	Major Sources	Estimated Industrial Water Use (mgd)
Tributaries											
Saline River											
Illinois	Franklin	0									0
"	Gallatin	4	3,335	3,335		.220	.220		66	Wells	0
"	Hamilton	1	3,000		3,000	.230		.230	77	Branch of Big Creek Impoundments	0
"	Hardin	0									0
"	Johnson	1	605		605	.018		.018	30	Reservoirs	0
"	Saline	5	17,910	300	17,610	1.311	.021	1.290	73	Saline R.,Dry Run Crk.,Wolf Crk.,Well	0
"	White	1	1,215		1,215	.080		.080	66	Indian Creek	0
"	Williamson	1	760	760		.023	.023		30	Wells	0
	Subtotal	13	26,825	4,395	22,430	1.882	.264	1.618	70		0
Tradewater River											
Kentucky	Caldwell	0									0
"	Christian	0									0
"	Crittenden	0									0
"	Hopkins	2	6,240	6,240		.280	.280		45	Lake Loch Mary, Wells	.2
"	Union	1	3,400		3,400	.180		.180	53	Tradewater River	0
"	Webster	3	6,350	850	5,500	.480	.085	.395	76	Tradewater R.,Dixon Lake, Wells	0
	Subtotal	6	15,990	7,090	8,900	.940	.365	.575	59		.2
	TOTAL	56	402,623	113,213	289,410	45.924	10.335	35.589	114		26.8

TABLE 10e

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

	1960			1980			2000			2020		
	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)	Pop. Served	Per Capita Use (gpcd)	Total Use (mgd)
Direct Drainage												
Area Designation 0-1												
From Central Supplies	90,663	89	8.0	108,800	98	10.7	129,000	108	13.9	167,000	120	20.0
Industrial			3.5			6.0			10.0			18.0
Subtotal			11.5			16.7			23.9			38.0
Area Designation 0-2												
From Central Supplies	173,975	146	25.3	245,300	160	39.3	329,000	165	54.3	465,000	170	79.0
Industrial			13.7			21.7			31.0			63.0
Subtotal			39.0			61.0			85.3			142.0
Area Designation 0-3												
From Central Supplies	80,400	93	7.5	160,800	102	16.4	249,000	112	27.9	333,000	123	41.0
Industrial			8.8			14.4			22.3			32.0
Subtotal			16.3			30.8			50.2			73.0
Other Areas in Basin												
From Central Supplies	14,800	153	2.3	20,100	161	3.2	27,000	168	4.5	38,000	171	6.5
Industrial			.6			1.2			2.1			3.8
Subtotal			2.9			4.4			6.6			10.3

TABLE 10e (cont'd)

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Water Use

Tributaries	1960 Pop. Served	1960 Per Capita Use (gpcd)	1960 Total Use (mgd)	1980 Pop. Served	1980 Per Capita Use (gpcd)	1980 Total Use (mgd)	2000 Pop. Served	2000 Per Capita Use (gpcd)	2000 Total Use (mgd)	2020 Pop. Served	2020 Per Capita Use (gpcd)	2020 Total Use (mgd)
Saline River												
From Central Supplies	26,825	70	1.9	35,700	87	3.1	45,000	97	4.4	61,000	103	6.3
Industrial			0			0.2			0.3			0.5
Subtotal			1.9			3.3			4.7			6.8
Tradewater River												
From Central Supplies	15,990	59	.9	18,900	80	1.5	27,000	93	2.5	43,000	105	4.5
Industrial			.2			0.5			1.0			1.5
Subtotal			1.1			2.0			3.5			6.0
Ohio River Main Stem - Evansville												
From Central Supplies Total	402,653	114	45.9	589,600	126	74.2	806,000	133	107.5	1,107,000	142	157.3
Industrial Total			26.8			44.0			66.7			118.8
GRAND TOTAL			72.7			118.2			174.2			276.1

TABLE 12a

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Direct Drainage						
Area Designation C						
Pennsyl.	Allegheny	14	1,537,940	Ohio River	1,537,940	622,000
"	Beaver	11	96,515	Ohio River	96,515	29,000
"	Washington	0				
"	Westmoreland	0				
	Subtotal	25	1,634,455		1,634,455	651,000
Area Designation E-1						
Ohio	Athens	0				
West Va.	Doddridge	0				
Ohio	Monroe	1	2,955	Sunfish Creek	2,955	3,000
West Va.	Pleasants	1	400	Ohio River	400	5,000
"	Tyler	1	2,700	Tanyard Run	2,700	2,500
Ohio	Washington	2	22,265	Ohio River	22,265	12,000
West Va.	Wetzel	5	9,070	Ohio River	9,070	15,500
"	Wood	3	50,800	Ohio River	50,800	57,000
	Subtotal	13	88,190		88,190	95,000

TABLE 12a (cont'd)

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Direct Drainage (cont'd)						
Area Designation E-2						
Ohio	Belmont	11	45,910	Ohio R., Captina Crk., McMahon Crk.	45,910	8,000
West Va.	Brooke	3	11,250	Ohio R., Mahan Crk., Buffalo Crk.	11,250	66,000
Ohio	Columbiana	9	58,160	Ohio R., Middle Fk, L. Beaver Crk.	58,160	6,000
West Va.	Hancock	4	31,740	Ohio River, Raccoon Crk.	31,740	11,000
Ohio	Jefferson	9	53,605	Ohio R., Cross Crk., Short Crk.	53,605	32,000
West Va.	Marshall	5	23,400	Ohio River, Graves Creek	23,400	17,000
"	Ohio	2	54,000	Ohio River, Wheeling Creek	54,000	23,000
	Subtotal	43	278,065		278,065	131,000
Other Areas in Basin						
Ohio	Harrison	1	3,260	Short Creek	3,260	300
"	Noble	1	2,000	Duck Creek	2,000	800
	Subtotal	2	5,260		5,260	1,100
Tributaries						
Middle Island Creek						
West Va.	Doddridge	1	1,000	Middle Island Creek	1,000	0
"	Pleasants	1	2,200	Middle Island Creek	2,200	500
"	Tyler	1	600	Middle Island Creek	600	0
	Subtotal	3	3,800		3,800	500

TABLE 12a (cont'd)

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Tributaries (cont'd)						
Chartiers Creek						
Pennsyl.	Allegheny	5	4,105	Chartiers Crk., Robinson Run	4,105	0
"	Washington	8	67,500	Chartiers Crk., Brush Run	67,500	16,600
	Subtotal	13	71,605		71,605	16,600
Raccoon Creek						
Pennsyl.	Beaver	1	8,000	Raccoon Creek	8,000	0
"	Washington	3	10,730	Raccoon Crk., Dutch Fork	10,730	300
	Subtotal	4	18,730		18,730	300
Hocking River						
Ohio	Athens	4	26,555	Hocking River, Sunday Creek	26,555	4,200
"	Fairfield	3	31,805	Hocking River, Rush Creek	31,805	9,800
"	Hocking	1	6,415	Hocking River	6,415	2,200
"	Morgan	0				
"	Perry	2	5,575	L.Bush Creek, Sunday Creek	5,575	1,300
"	Washington	0				
	Subtotal	10	70,350		70,350	17,500
	TOTAL	113	2,170,455		2,170,455	913,000

*NOT to be interpreted as waste loads to the stream.

TABLE 13a

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Direct Drainage				
Area Designation C				
Domestic and Commercial	1,634,455	1,782,000	2,059,000	2,435,000
Industrial	651,000	768,000	990,000	1,380,000
Subtotal	2,285,455	2,550,000	3,049,000	3,815,000
Area Designation E-1				
Domestic and Commercial	88,190	103,200	134,900	178,000
Industrial	95,000	134,900	193,800	268,000
Subtotal	183,190	238,100	328,700	446,000
Area Designation E-2				
Domestic and Commercial	278,065	308,600	364,300	456,000
Industrial	131,000	136,200	161,100	215,000
Subtotal	409,065	444,800	525,400	671,000
Other Areas in Basin				
Domestic and Commercial	5,260	7,900	10,300	13,900
Industrial	1,100	1,800	2,700	4,400
Subtotal	6,360	9,700	13,000	18,300

TABLE 13a (cont'd)

OHIO RIVER MAIN STEM - UPPER

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Minor Tributaries				
Middle Island Creek				
Domestic and Commercial	3,800	4,500	5,800	7,700
Industrial	500	700	1,000	1,400
Subtotal	4,300	5,200	6,800	9,100
Chartiers Creek				
Domestic and Commercial	71,605	78,000	90,200	107,000
Industrial	16,600	19,600	25,200	35,200
Subtotal	88,205	97,600	115,400	142,200
Raccoon Creek				
Domestic and Commercial	18,730	20,400	23,600	27,900
Industrial	300	400	500	600
Subtotal	19,030	20,800	24,100	28,500
Hocking River				
Domestic and Commercial	70,350	135,100	198,400	276,000
Industrial	17,500	36,000	63,900	112,000
Subtotal	87,850	171,100	262,300	388,000
Upper Ohio River Basin				
Domestic and Commercial Total	2,170,455	2,439,700	2,886,500	3,501,500
Industrial Total	913,000	1,097,600	1,438,200	2,016,600
GRAND TOTAL	3,083,455	3,537,300	4,324,700	5,518,100

*NOT to be interpreted as waste loads to the stream.

TABLE 12b

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*: Domestic & Commercial	Estimated Industrial
Direct Drainage						
Area Designation H-1						
Kentucky	Greenup	6	9,870	Ohio River, Pond Run	9,870	1,200
"	Lewis	1	1,880	Salt Lick Creek	1,880	800
Ohio	Pike	0				
"	Scioto	4	41,200	Ohio River	41,200	16,000
	Subtotal	11	52,950		52,950	18,000
Area Designation H-2						
Kentucky	Boyd	3	35,375	Ohio River, Hood Creek	35,375	19,000
West Va.	Cabell	1	75,000	Ohio River	75,000	25,000
Ohio	Lawrence	4	20,930	Ohio River	20,930	25,000
West Va.	Wayne	1	4,000	Ohio River	4,000	0
	Subtotal	9	135,305		135,305	69,000
Area Designation H-3						
Ohio	Gallia	1	8,775	Ohio River	8,775	4,500
"	Jackson	1	1,745	Symmes Creek	1,745	700
West Va.	Jackson	2	3,900	Ohio River, Mill Creek	3,900	3,200
"	Mason	2	1,205	Ohio River	1,205	3,200
Ohio	Meigs	2	6,715	Ohio River	6,715	1,400
"	Vinton	0		Ohio River		
	Subtotal	8	22,340		22,340	13,000

TABLE 12b (cont'd)

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Areas	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Raw Waste Production Before Treatment Population Equivalent* Estimated Industrial
Tributaries						
Raccoon Creek						
Ohio	Athens	0				
"	Gallia	1	330	Raccoon Creek	330	0
"	Hocking	0				
"	Jackson	1	5,725	Raccoon Creek	5,725	900
"	Meigs	0				
"	Vinton	1	1,530	Raccoon Creek	1,530	2,600
	Subtotal	3	7,585		7,585	3,500
Twelve Pole Creek						
West Va.	Cabell	0				
"	Lincoln	0				
"	Mingo	0				
"	Wayne	2	1,600	Twelve Pole Creek	1,600	0
	Subtotal	2	1,600		1,600	0
Tygarts Creek						
Kentucky	Carter	1	1,400	Tygarts Creek	1,400	0
"	Greenup	0				
	Subtotal	1	1,400		1,400	0
	TOTAL	34	221,180		221,180	103,500

*NOT to be interpreted as waste loads to the stream.

TABLE 13b

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Direct Drainage				
Area Designation H-1				
Domestic and Commercial	52,950	71,000	92,100	123,000
Industrial	18,000	25,900	41,900	72,000
Subtotal	70,950	96,900	134,000	195,000
Area Designation H-2				
Domestic and Commercial	135,305	170,500	204,300	257,000
Industrial	69,000	98,700	149,700	234,000
Subtotal	204,305	269,200	354,000	491,000
Area Designation H-3				
Domestic and Commercial	22,340	28,100	34,400	42,000
Industrial	13,000	20,700	37,600	72,000
Subtotal	35,340	48,800	72,000	114,000
Minor Tributaries				
Raccoon Creek				
Domestic and Commercial	7,585	9,600	11,700	14,000
Industrial	3,500	5,600	10,100	19,000
Subtotal	11,085	15,200	21,800	33,000

TABLE 13b (cont'd)

OHIO RIVER MAIN STEM - HUNTINGTON

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Minor Tributaries (cont'd)				
Twelve Pole Creek				
Domestic and Commercial	1,600	2,000	2,400	3,000
Industrial	0	0	0	0
Subtotal	1,600	2,000	2,400	3,000
Tygarts Creek				
Domestic and Commercial	1,400	1,500	1,500	1,400
Industrial	0	0	0	0
Subtotal	1,400	1,500	1,500	1,400
Ohio River Basin - Huntington				
Domestic and Commercial Total	221,180	282,700	346,400	440,400
Industrial Total	103,500	150,900	239,300	397,000
GRAND TOTAL	324,680	433,600	585,700	837,400

*NOT to be interpreted as waste loads to the stream.

TABLE 12c

OHIO RIVER MAIN STEM - CINCINNATI

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Areas	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Direct Drainage						
Area Designation K-1						
Indiana	Dearborn	3	14,700	Ohio River	14,700	26,500
Kentucky	Gallatin	1	980	Ohio River	980	0
Indiana	Ohio	1	2,230	Ohio River	2,230	700
"	Ripley	5	7,380	L.Laughery Crk.,Laughery Crk.	7,380	4,000
"	Switzerland	1	1,500	Ohio River	1,500	800
	Subtotal	11	26,790		26,790	32,000
Area Designation K-2						
Kentucky	Boone	1	2,000	S.Fk.Gunpowder Crk.	2,000	700
"	Campbell	3	147,665	Ohio River, Four Mile Crk.	147,665	68,000
Ohio	Clermont	2	3,710	Ohio River, Bullskin Crk.	3,710	200
"	Hamilton	7	787,340	Ohio River, Mill Creek	787,340	1,170,000
Kentucky	Kenton	3	9,810	Dry Crk., Pleasant Run Crk.	9,810	11,600
	Subtotal	16	950,525		950,525	1,260,500
Area Designation K-3						
Ohio	Adams	4	6,245	Ohio R.,Brush Crk.,Brush Crk.	6,245	0
Kentucky	Bracken	1	1,460	Ohio River	1,460	500
Ohio	Brown	2	4,785	Town Run, Ohio River	4,785	1,000
Kentucky	Mason	1	8,485	Ohio River	8,485	8,500
	Subtotal	8	20,975		20,975	10,000

TABLE 12c (cont'd)

OHIO RIVER MAIN STEM - CINCINNATI

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent** Domestic & Commercial	Estimated Industrial
Tributary						
Mill Creek						
Ohio	Butler	0				0
"	Hamilton	1	2,830	Tributary of Mill Creek	2,830	*
	Subtotal	1	2,830		2,830	0
	TOTAL	36	1,001,120		1,001,120	1,302,500

*Included with Hamilton County, Ohio.
**NOT to be interpreted as waste loads to the stream.

TABLE 13c

OHIO RIVER MAIN STEM - CINCINNATI

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent**			
	1960	1980	2000	2020
Direct Drainage				
Area Designation K-1				
Domestic and Commercial	26,790	39,600	59,500	92,000
Industrial	32,000	52,800	94,100	188,000
Subtotal	58,790	92,400	153,600	280,000
Area Designation K-2				
Domestic and Commercial	950,525	1,188,000	1,416,000	1,625,000
Industrial	1,260,500	1,941,000	2,900,000	4,512,000
Subtotal	2,211,025	3,129,000	4,316,000	6,137,000
Area Designation K-3				
Domestic and Commercial	20,975	25,400	40,700	52,000
Industrial	10,000	18,400	32,200	65,000
Subtotal	30,975	43,800	72,900	117,000
Minor Tributary				
Mill Creek				
Domestic and Commercial	2,830	3,500	4,200	5,000
Industrial	*	*	*	*
Subtotal	2,830	3,500	4,200	5,000
Ohio River Basin - Cincinnati				
Domestic and Commercial Total	1,001,120	1,256,500	1,520,400	1,774,000
Industrial Total	1,302,500	2,012,200	3,026,300	4,765,000
GRAND TOTAL	2,303,620	3,268,700	4,546,700	6,539,000

* Included in Area K-2
** NOT to be interpreted as waste loads to the stream

TABLE 12d

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Direct Drainage						
Area Designation N-1						
Kentucky	Breckinridge	2	2,710	Hardins Creek, Ohio River	2,710	0
Indiana	Crawford	2	400	Dry Run	400	100
"	Harrison	2	3,100	Little Indian Creek	3,100	500
Kentucky	Meade	0		Ohio River		5,000
	Subtotal	6	6,210		6,210	5,600
Area Designation N-2						
Kentucky	Bullitt	0				
Indiana	Clark	6	61,000	Ohio R.,Cane Run,Pleasant Run	61,000	6,500
"	Floyd	1	37,800	Ohio River	37,800	14,500
Kentucky	Jefferson	7	427,685	Ohio River,Mill Crk.,L.Goose Crk.	427,685	784,000
"	Oldham	1	2,170	Brush Creek	2,170	0
	Subtotal	15	528,655		528,655	805,000
Area Designation N-3						
Kentucky	Carroll	0				
Indiana	Jefferson	2	11,170	Ohio River	11,170	11,400
Kentucky	Trimble	0				
	Subtotal	2	11,170		11,170	11,400
Other Areas in Basin						
Kentucky	Hardin	2	4,390	Ohio River, Brush Fork	4,390	0
	Subtotal	2	4,390		4,390	0

TABLE 12d (cont'd)

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*	
					Domestic & Commercial	Estimated Industrial
Tributaries						
Blue River						
Indiana	Crawford	0				
"	Floyd	0				
"	Harrison	0				
"	Orange	0				
"	Washington	1	4,540	W. Fk. Blue River	4,540	4,300
	Subtotal	1	4,540		4,540	4,300
	TOTAL	26	554,965		554,965	826,300

*NOT to be interpreted as waste loads to the stream.

TABLE 13d

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Direct Drainage				
Area Designation N-1				
Domestic and Commercial	6,210	12,800	21,500	32,000
Industrial	5,600	14,000	26,400	53,000
Subtotal	11,810	26,800	47,900	85,000
Area Designation N-2				
Domestic and Commercial	528,655	729,500	941,000	1,100,000
Industrial	805,000	1,497,300	2,560,000	4,363,000
Subtotal	1,333,655	2,226,800	3,501,000	5,463,000
Area Designation N-3				
Domestic and Commercial	11,170	22,300	31,900	47,000
Industrial	11,400	25,500	46,500	114,000
Subtotal	22,570	47,800	78,400	161,000
Other Areas in Basin				
Domestic and Commercial	4,390	3,300	6,000	12,000
Industrial	0	300	700	1,000
Subtotal	4,390	3,600	6,700	13,000

TABLE 13d (cont'd)

OHIO RIVER MAIN STEM - LOUISVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Minor Tributary				
Blue River				
Domestic and Commercial	4,540	8,100	12,700	19,000
Industrial	4,300	8,200	14,700	38,000
Subtotal	8,840	16,300	27,400	57,000
Ohio River Basin - Louisville				
Domestic and Commercial Total	554,965	776,000	1,013,100	1,210,000
Industrial Total	826,300	1,545,300	2,648,300	4,569,000
GRAND TOTAL	1,381,265	2,321,300	3,661,400	5,779,000

*NOT to be interpreted as waste loads to the stream.

TABLE 12e

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Direct Drainage						
Area Designation 0-1						
Kentucky	Ballard	2	1,610	Shawnee Crk., Humphrey Crk.	1,610	0
"	Caldwell	0				
"	Crittenden	1	2,470	Rush Creek	2,470	400
Illinois	Gallatin	1	700	Ohio River	700	0
"	Hardin	2	1,790	Ohio River	1,790	100
"	Johnson	1	1,000	Little Cache Creek	1,000	0
Kentucky	Livingston	0				
"	McCracken	2	34,880	Ohio River	34,880	15,000
Illinois	Massac	3	10,730	Ohio River	10,730	100
"	Pope	1	850	Ohio River	850	0
Indiana	Posey	1	5,970	Mill Creek	5,970	3,600
Illinois	Pulaski	3	3,985	Ohio River, Trinity Slough	3,985	200
"	Saline	0				
Kentucky	Union	2	4,995	Ohio River, Lost Creek	4,995	100
"	Webster	0				
	Subtotal	19	68,980		68,980	19,500
Area Designation 0-2						
Kentucky	Henderson	1	16,890	Ohio River	16,890	3,000
Indiana	Vanderburgh	2	141,500	Ohio River	141,500	119,000
	Subtotal	3	158,390		158,390	122,000

TABLE 12e (cont'd)

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent* Domestic & Commercial	Estimated Industrial
Direct Drainage (cont'd)						
Area Designation 0-3						
Kentucky	Daviess	1	42,470	Ohio River	42,470	40,000
"	Hancock	2	1,490	Lead Crk., Ohio River	1,490	200
"	McLean	0				
Indiana	Perry	2	8,425	Ohio River	8,425	1,200
"	Spencer	1	2,470	Ohio River	2,470	500
"	Warrick	2	6,200	Cypress Creek, Ohio River	6,200	2,600
	Subtotal	8	61,055		61,055	44,500
Other Areas in Basin						
Illinois	Alexander	1	9,000	Ohio River	9,000	0
Indiana	DuBois	0		Little Pigeon Creek		7,800
"	Gibson	2	9,240	W. Fk. Pigeon Creek, Richland Crk.	9,240	
	Subtotal	3	18,240		18,240	7,800
Tributaries						
Saline River						
Illinois	Franklin	0				
"	Gallatin	1	700	N. Fk. Saline River	700	300
"	Hamilton	1	2,500	Br. of N. Fk. Saline River	2,500	500
"	Hardin	0				
"	Johnson	0				
"	Saline	2	12,725	Middle Fk. Saline R., Eldorado Ditch	12,725	600
"	White	1	1,300	Bear Creek	1,300	0
"	Williamson	0				
	Subtotal	5	17,225		17,225	1,400

TABLE 12e (cont'd)

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base Municipal and Industrial Organic Waste Production

State	County	No. of Systems	Population Served	Major Discharge Area	Raw Waste Production Before Treatment Population Equivalent*: Domestic & Commercial	Estimated Industrial
Tributaries (cont'd)						
Tradewater River						
Kentucky	Caldwell	0				
"	Christian	0				
"	Crittenden	0				
"	Hopkins	1	3,000	Tradewater River	3,000	100
"	Union	1	2,210	Cypress Creek	2,210	200
"	Webster	2	5,115	Owens Crk., Vaughan Ditch	5,115	1,000
	Subtotal	4	10,325		10,325	1,300
	TOTAL	42	334,215		334,215	196,500

*NOT to be interpreted as waste loads to the stream.

TABLE 13e

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Direct Drainage				
Area Designation 0-1				
Domestic and Commercial	68,980	82,800	98,000	127,000
Industrial	19,500	33,200	56,200	99,000
Subtotal	88,480	116,000	154,200	226,000
Area Designation 0-2				
Domestic and Commercial	158,390	223,300	299,300	424,000
Industrial	122,000	194,000	278,200	564,000
Subtotal	280,390	417,300	577,500	988,000
Area Designation 0-3				
Domestic and Commercial	61,055	122,100	189,300	253,000
Industrial	44,500	73,000	112,600	164,000
Subtotal	105,555	195,100	301,900	417,000
Other Areas in Basin				
Domestic and Commercial	10,940	13,100	15,500	20,100
Industrial	7,800	13,300	22,500	40,000
Subtotal	18,740	26,400	38,000	60,100

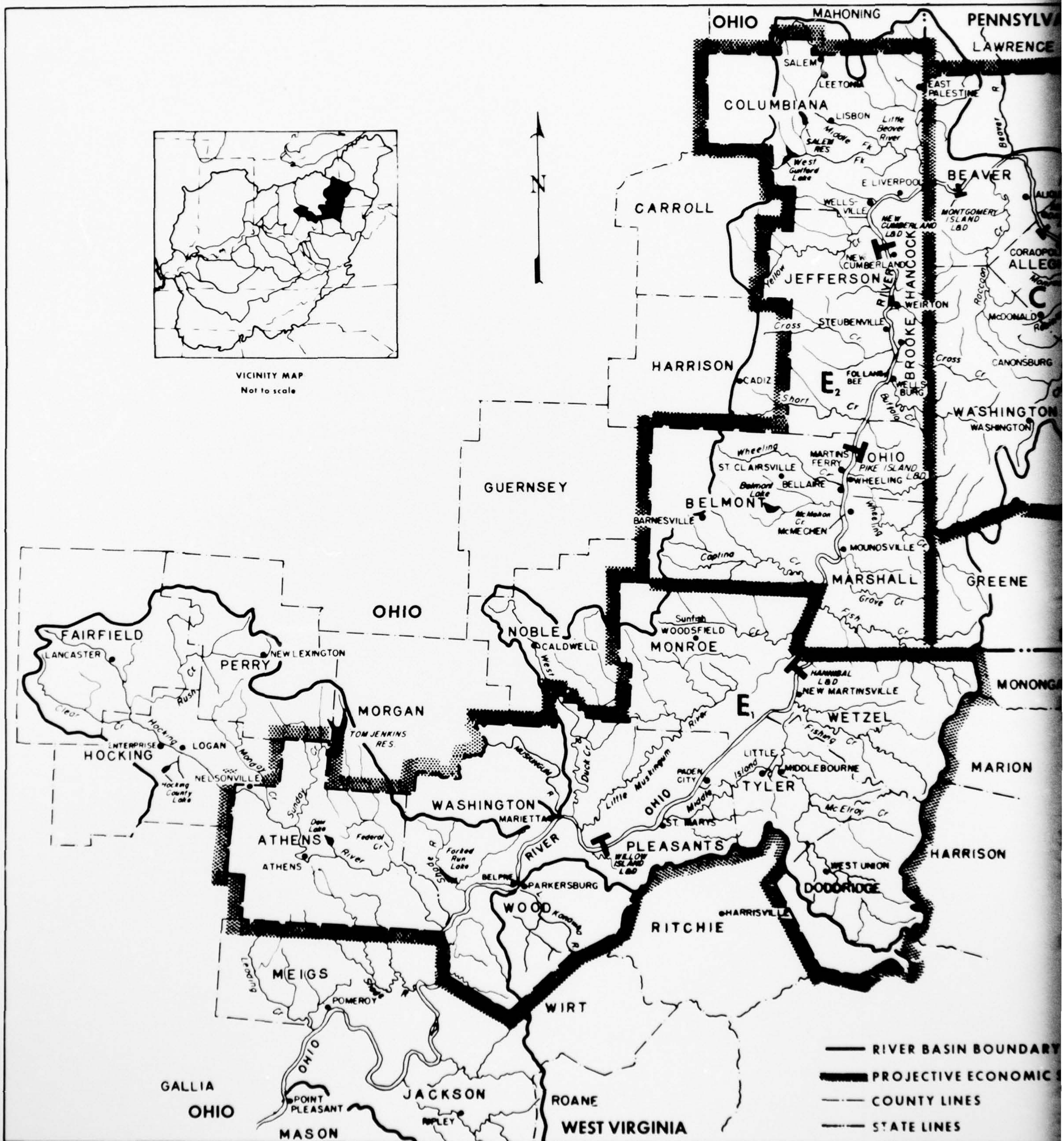
TABLE 13e (cont'd)

OHIO RIVER MAIN STEM - EVANSVILLE

Direct Drainage and Minor Tributaries
Base and Projected Municipal and Industrial Organic Waste Production

	Raw Waste Production Before Treatment Population Equivalent*			
	1960	1980	2000	2020
Minor Tributaries				
Saline River				
Domestic and Commercial	17,225	20,700	24,500	31,700
Industrial	1,400	2,400	4,000	7,000
Subtotal	18,625	23,100	28,500	38,700
Tradewater River				
Domestic and Commercial	10,325	12,400	14,700	19,000
Industrial	1,300	2,200	3,700	7,000
Subtotal	11,625	14,600	18,400	26,000
Ohio River Basin - Evansville				
Domestic and Commercial Total	326,915	474,400	641,300	874,800
Industrial Total	196,500	318,100	477,200	881,000
GRAND TOTAL	523,415	792,500	1,118,500	1,755,800

*NOT to be interpreted as waste loads to the stream.



VICINITY MAP
Not to scale
N
OHIO
MAHONING
PENNSYLVA
LAWRENCE
COLUMBIANA
SALEM
LEETONIA
EAST PALESTINE
LISBON
BEAVER
CARROLL
JEFFERSON
STEUBENVILLE
WEIRTON
HANCOCK
BROOKE
ALLEG
HARRISON
CADIZ
E2
WASHINGTON
GUERNSEY
BELMONT
ST. CLAIRSVILLE
BELLAIRE
WHEELING
BARNESVILLE
MOUNDSVILLE
MARSHALL
GREENE
OHIO
NOBLE
CALDWELL
MONROE
WOODSFIELD
FAIRFIELD
LANCASTER
PERRY
NEW LEXINGTON
MORGAN
HOCKING
LOGAN
NELSONVILLE
E1
WETZEL
NEW MARTINSVILLE
MONONGA
TYLER
MIDDLEBOURNE
MARION
WASHINGTON
MARIETTA
ATHENS
ATHENS
PLEASANTS
ST MARYS
PARKERSBURG
WOOD
HARRISON
DODDRIDGE
WEST UNION
RITCHIE
HARRISVILLE
MEIGS
POMEROY
WIRT
GALLIA
OHIO
POINT PLEASANT
JACKSON
RIPLEY
ROANE
MASON
WEST VIRGINIA
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC S
COUNTY LINES
STATE LINES

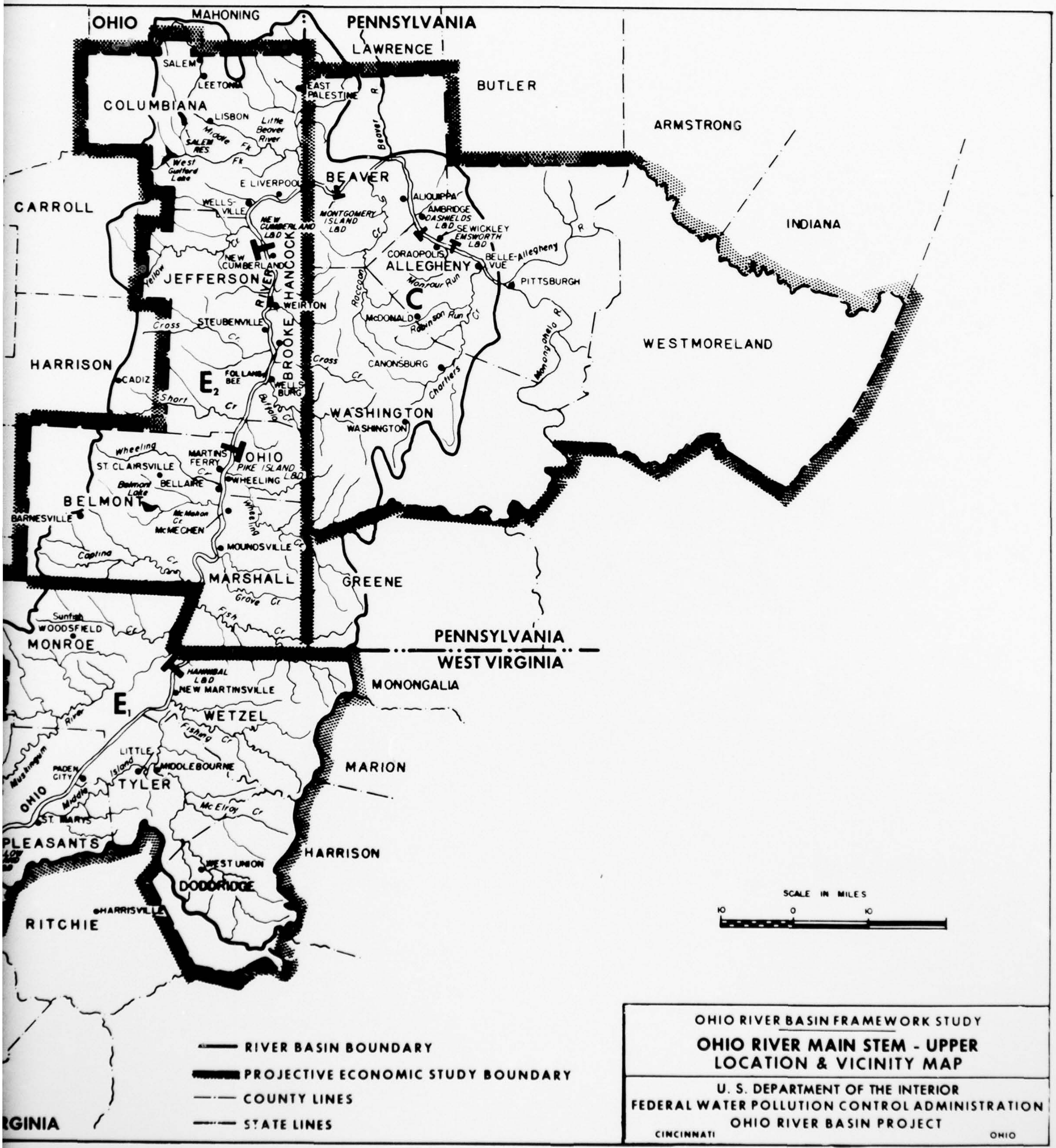


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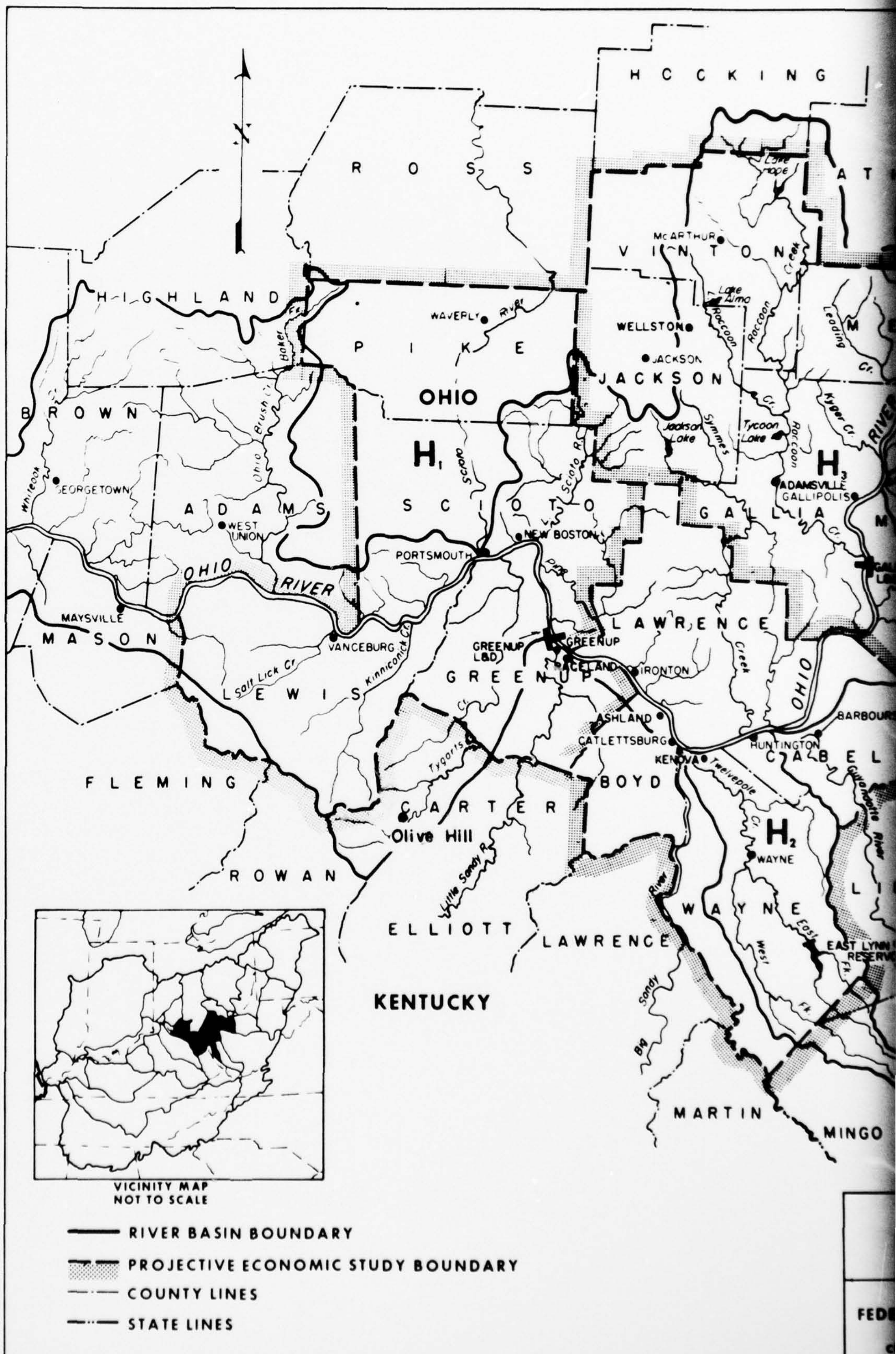
FIGURE 13.1


HOCKING
ROSS
VINTON
HIGHLAND
PIKE
JACKSON
OHIO
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
MASON
LEWIS
GREENUP
CABELL
BOYD
CARTER
FLEMING
ROWAN
ELLIOTT
LAWRENCE
WAYNE
MARTIN
MINGO
KENTUCKY
H1
H2
H3
McARTHUR
WAVERLY
WELLSTON
JACKSON
GEORGETOWN
WEST UNION
NEW BOSTON
PORTSMOUTH
MAYSVILLE
VANCEBURG
GREENUP L&D
GREENUP
RACELAND
IRONTON
ASHLAND
CATLETTSBURG
KENOVA
HUNTINGTON
WAYNE
ADAMSVILLE
GALLIPOLIS
Olive Hill
EAST LYNN RESERVOIR
OHIO RIVER
Lake Hope
Lake Alma
Jackson Lake
Tycoon Lake
Raccoon
Symmes
Leading Cr.
Kyger Cr.
Scioto R.
Scioto
Ohio Brush Cr.
Whiteoak
Salt Lick Cr.
Kinniconick Cr.
Tygarts Cr.
Little Sandy R.
Big Sandy River
Twelvepole Cr.
East Fk.
West Fk.
Guyandotte River
Baker Fk.
Paint
VICINITY MAP NOT TO SCALE
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STUDY BOUNDARY
COUNTY LINES
STATE LINES

RIVER BASIN BOUNDARY

PROJECTIVE ECONOMIC STUDY BOUNDARY

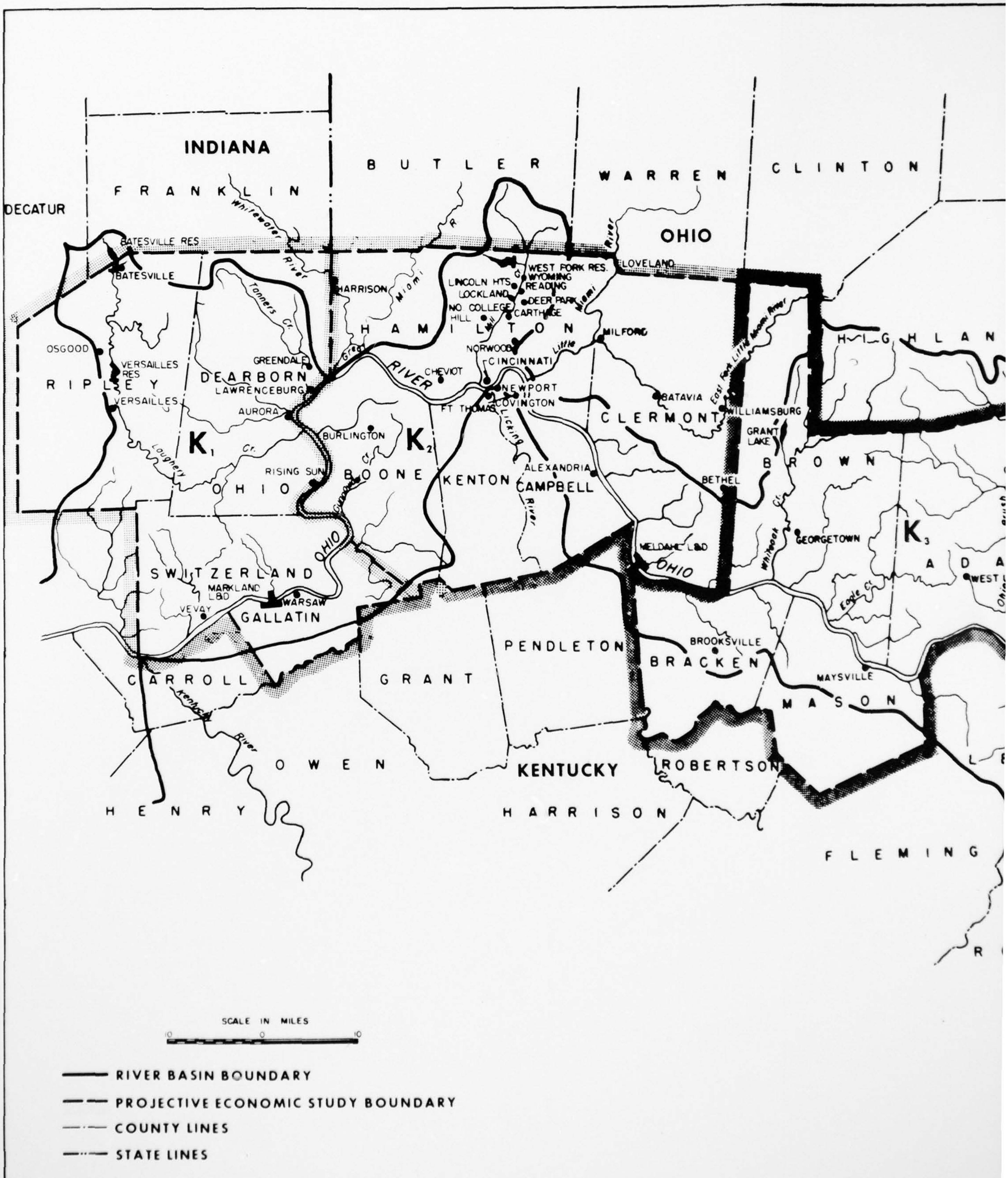
COUNTY LINES

STATE LINES

OHIO RIVER BASIN FRAMEWORK STUDY

OHIO RIVER MAIN STEM - HUNTINGTON
LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO


INDIANA
OHIO
KENTUCKY
DECATUR
FRANKLIN
BUTLER
WARREN
CLINTON
RIPLEY
DEARBORN
HAMILTON
CLERMONT
HIGHLAN
BROWN
ADA
OHIO
BOONE
KENTON
CAMPBELL
SWITZERLAND
GALLATIN
CARROLL
GRANT
PENDLETON
BRACKEN
MASON
ROBERTSON
OWEN
HENRY
HARRISON
FLEMING
K1
K2
K3
BATESVILLE RES
BATESVILLE
OSGOOD
VERSAILLES RES
VERSAILLES
GREENDALE
LAWRENCEBURG
AURORA
HARRISON
LINCOLN HTS
LOCKLAND
WEST FORK RES.
WYOMING
READING
DEER PARK
CARTHAGE
NO COLLEGE HILL
NORWOOD
CINCINNATI
CHEVIOT
NEWPORT
COVINGTON
FT THOMAS
LOVELAND
MILFORD
BATAVIA
WILLIAMSBURG
GRANT LAKE
BETHEL
BURLINGTON
RISING SUN
ALEXANDRIA
GEORGETOWN
MELDAHL L&D
MARKLAND L&D
VEVAY
WARSAW
BROOKSVILLE
MAYSVILLE
WEST
Whitewater River
Tanners Cr.
Great Miami R
Mill Cr.
Little Miami River
East Fork Little Miami River
Laughery Cr.
Gunpowder Cr.
Licking River
Kentucky River
Whiteoak Cr.
Eagle Cr.
RIVER
OHIO
SCALE IN MILES
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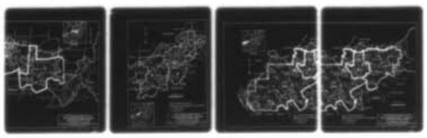
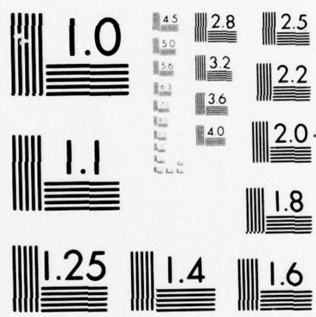
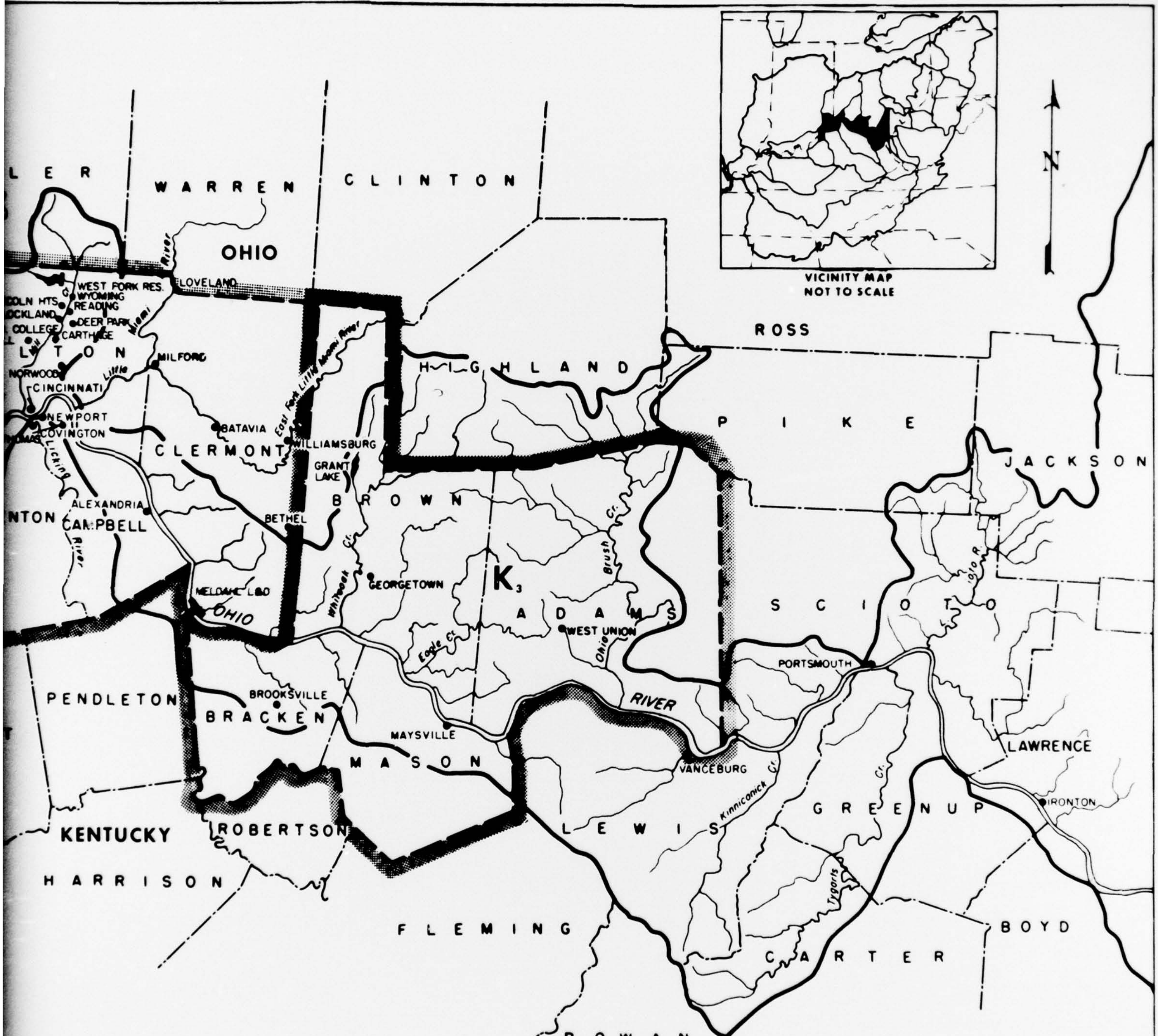
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STUDY BOUNDARY
COUNTY LINES
STATE LINES





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



OHIO RIVER BASIN FRAMEWORK STUDY

OHIO RIVER MAIN STEM-CINCINNATI
LOCATION & VICINITY MAP

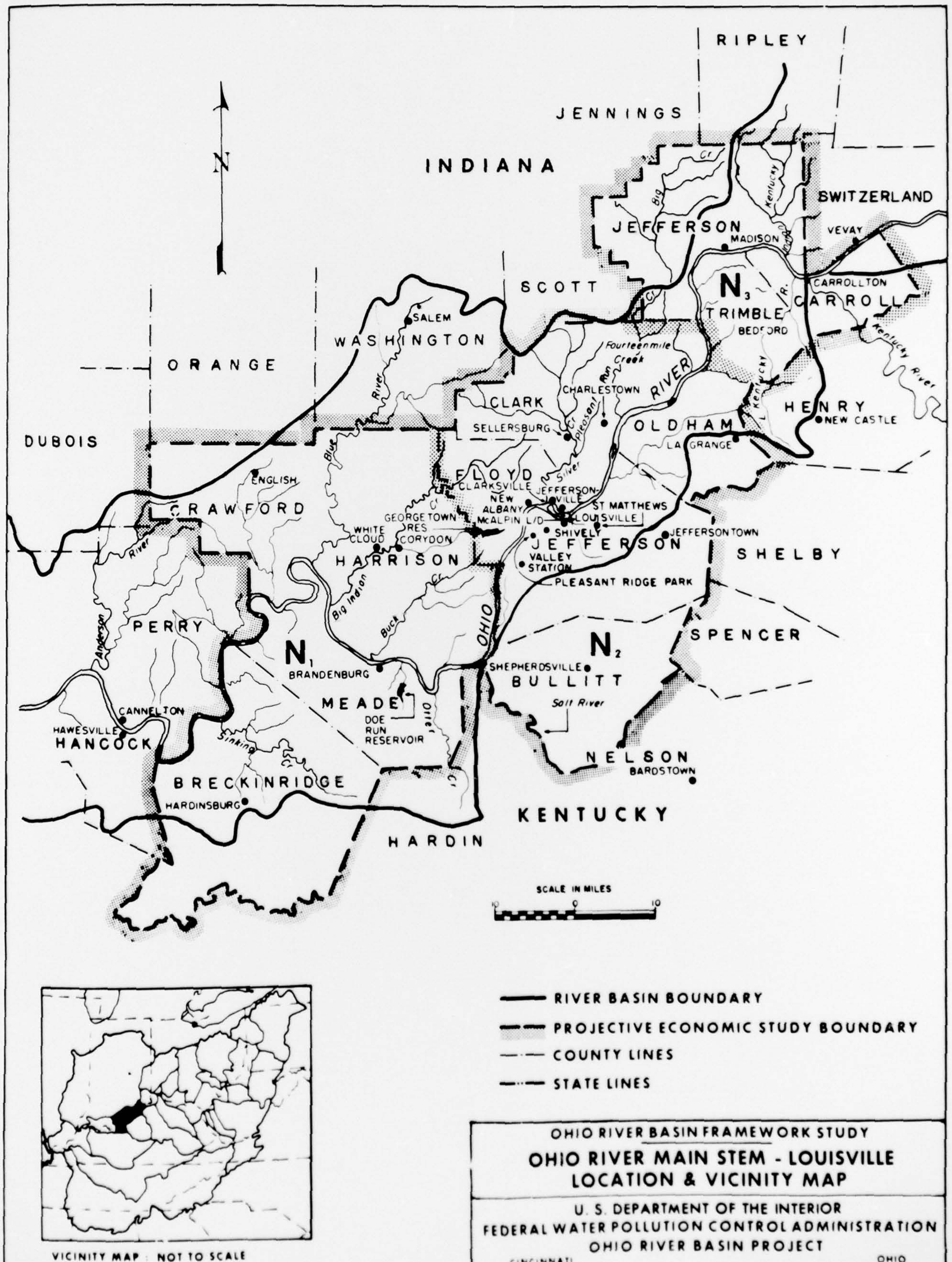
U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT

CINCINNATI — OHIO

13 110

FIGURE 13 3

2



OHIO RIVER BASIN FRAMEWORK STUDY

OHIO RIVER MAIN STEM - LOUISVILLE LOCATION & VICINITY MAP

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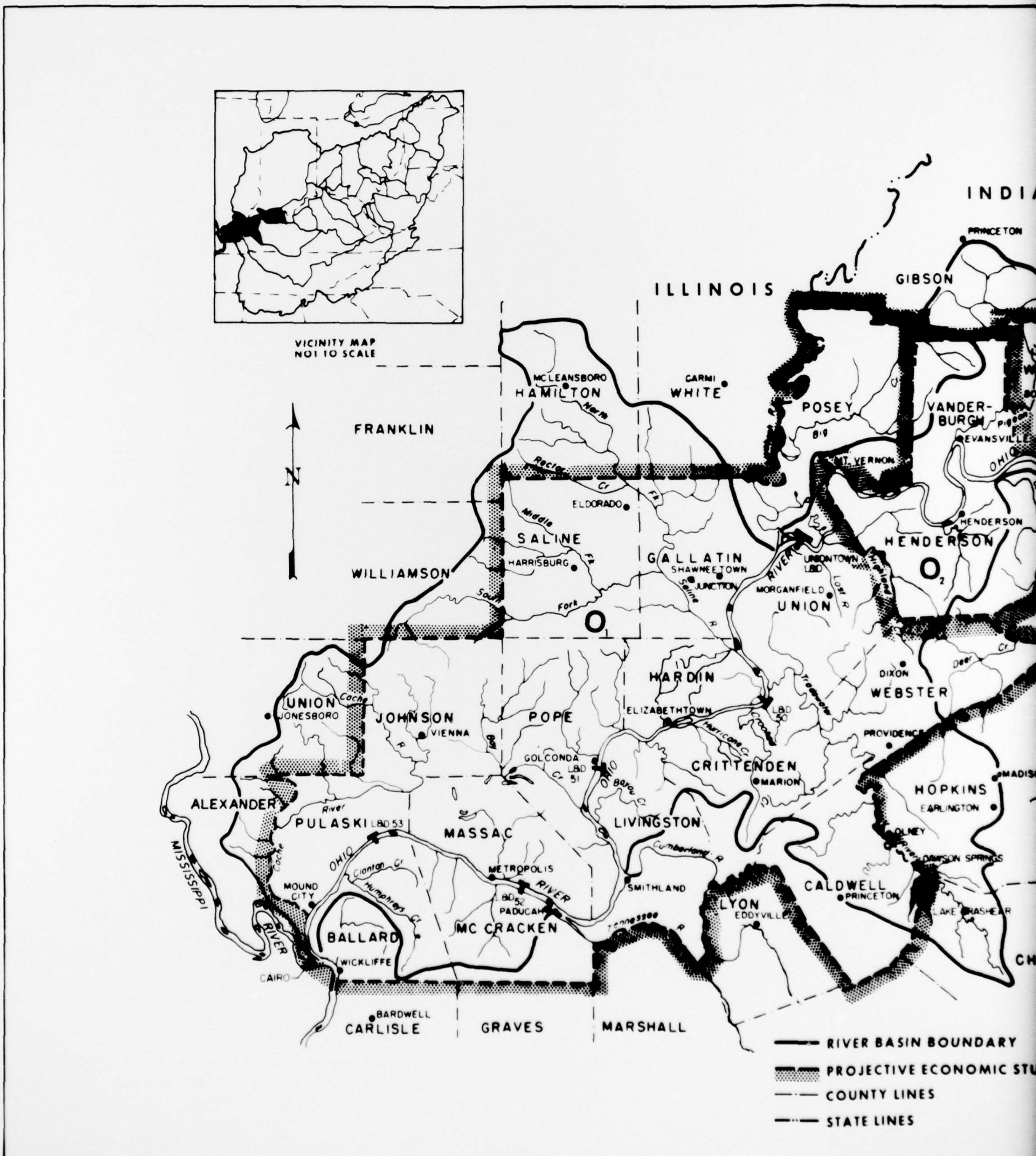
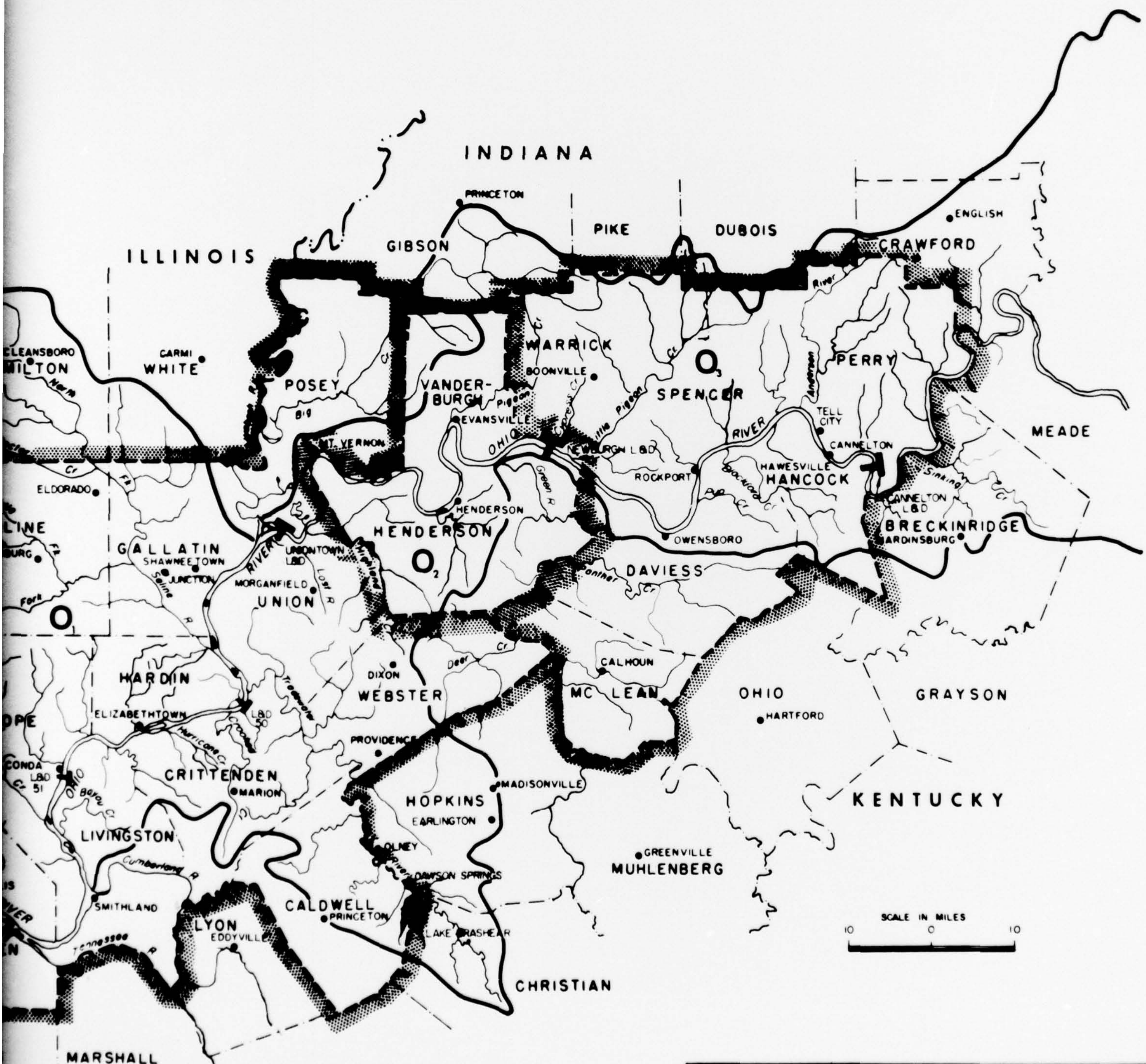
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

FIGURE 13.4



VICINITY MAP
NOT TO SCALE
ILLINOIS
INDIA
PRINCETON
GIBSON
HAMILTON
MC LEANSBORO
CARMI
WHITE
POSEY
VANDER-
BURGH
EVANSVILLE
MT. VERNON
HENDERSON
FRANKLIN
ELDORADO
SALINE
HARRISBURG
WILLIAMSON
GALLATIN
SHAWNEETOWN
JUNCTION
UNIONTOWN
LBD
MORGANFIELD
UNION
O_1
O_2
DIXON
WEBSTER
HARDIN
UNION
JONESBORO
JOHNSON
VIENNA
POPE
ELIZABETHTOWN
PROVIDENCE
GOLCONDA
LBD 51
CRITTENDEN
MARION
HOPKINS
MADISO
EARLINGTON
ALEXANDER
PULASKI
LBD 53
MASSAC
LIVINGSTON
OLNEY
DAWSON SPRINGS
MISSISSIPPI
MOUND CITY
METROPOLIS
LBD 52
PADUCAH
SMITHLAND
CALDWELL
PRINCETON
LYON
EDDYVILLE
LAKE BRASHEAR
BALLARD
MC CRACKEN
WICKLIFFE
CAIRO
RIVER
OHIO
BARDWELL
CARLISLE
GRAVES
MARSHALL
CHR
RIVER BASIN BOUNDARY
PROJECTIVE ECONOMIC STU
COUNTY LINES
STATE LINES



RIVER BASIN BOUNDARY

PROJECTIVE ECONOMIC STUDY BOUNDARY

COUNTY LINES

STATE LINES

OHIO RIVER BASIN FRAMEWORK STUDY

OHIO RIVER MAIN STEM - EVANSVILLE LOCATION & VICINITY MAP

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
OHIO RIVER BASIN PROJECT
CINCINNATI OHIO

13 112

FIGURE 13 5

2